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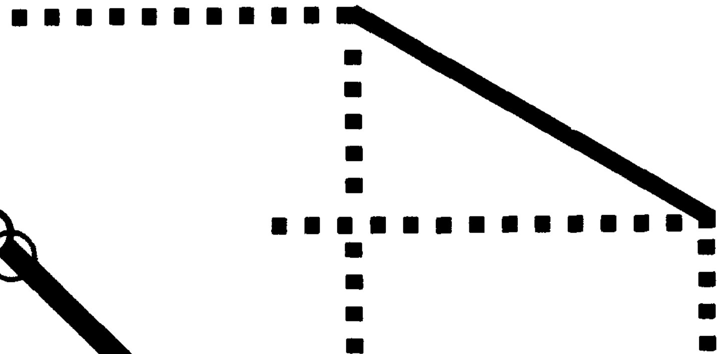
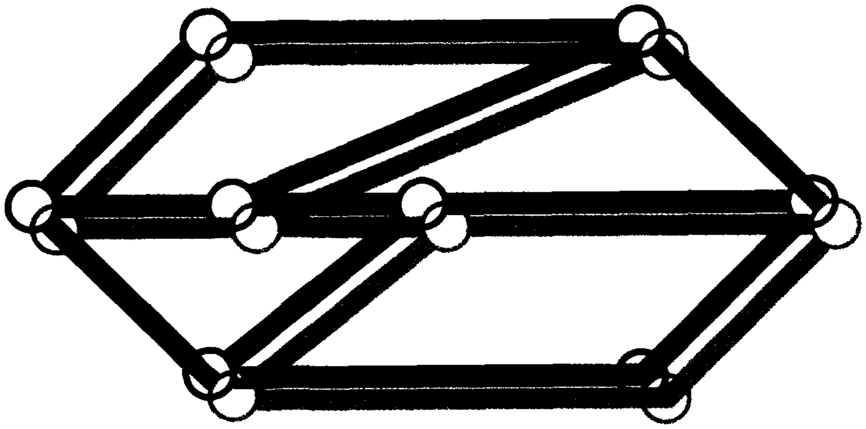
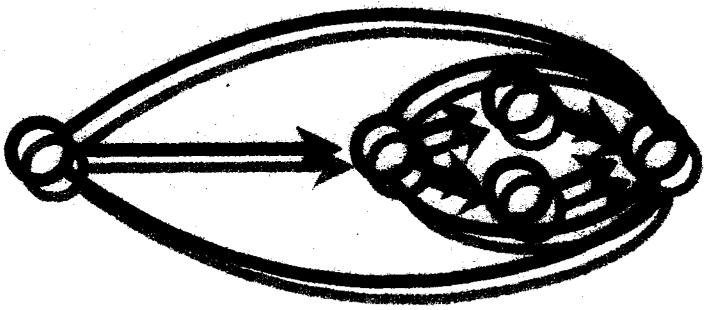
Scheduling Guide

For Program Managers







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SCHEDULING GUIDE FOR PROGRAM MANAGERS

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PREFACE

This guide provides an introduction to scheduling. It is the second version of a 1986 *publication prepared by Mr. David D. Acker, Mr. J. Stanley Baumgartner and Mr. Michael* B. Patterson. The 1994 revision was developed by Mr. William W. Bahnmaier and Mr. Paul T. McMahon. Ms. Christine Royer retyped the manuscript, and Mr. Gregory Caruth and Ms. Deborah Gonzalez provided the charts and graphs. Editing was performed by Mrs. Esther M. Farria and Ms. Alberta Ladymon and printing by Mr. Robert W. Ball of the Defense Systems Management College (DSMC) Press.

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1

INTRODUCTION

In its simplest form, a schedule is nothing more than a listing of activities and events, organized by time. In its more complex form, it is a process that examines all program activities in terms of realistic constraints of time, funds and people; i.e., resources. In program management practice, the schedule is one of the most powerful planning, control and communications tools. Properly executed, scheduling supports time and cost estimates, opens communications between personnel involved in program activities, and establishes a commitment to program activities.

Scheduling is one of the most important aspects of the program management function — planning. This is readily apparent when the program structure or schedule is prepared as part of a program's acquisition strategy and in the development of risk, financial and technical management plans.

In addition, scheduling is a key element in accomplishing the other management functions — controlling, organizing, staffing and leading. For example, controlling is what is done to keep abreast of program execution. To achieve the goals, it is necessary to know whether the program is behind, on or ahead of schedule, and what adjustments are necessary to keep the program on schedule once it's back on track.

Why does a program manager (PM) schedule? The simple answer is that he/she needs a road map for all program players. In reality, scheduling accomplishes far more than the production of "wall paper" network charts. Scheduling supports key program management objectives such as developing and fielding cost-effective systems. As the scheduling process is explored, the objectives and the means by which they can be achieved will be addressed.

This guide is an introduction to scheduling. It is meant for people who already have some experience in program management and for those enrolled in courses at the Defense Systems Management College (DSMC).

The following chapters will explain and illustrate scheduling concepts and techniques. Specifically, they will show how to plan schedules, use Gantt and milestone charts, develop and interpret network and line-of-balance charts, manage time as a resource, and use commercial and government software scheduling packages.

2
SCHEDULE PLANNING

2.1 SCHEDULING PROCESS

One of the first steps in defining a project or program is to create a Work Breakdown Structure (WBS). Guidance on creating a WBS is provided in MILSTD-881B of 25 March 1993. The contract WBS goes to levels below the third level and includes process/work activities at the lowest levels. These activities are the basis for the work packages for cost accounting and the Cost Schedule Control System Criteria. The work packages show the clear link between the organizational structure and the WBS. They also contain the tasks or activities which are depicted on the schedule charts described in this guidebook.

Using a WBS as the starting point for identifying activities for constructing a network or Gantt chart is an efficient approach; however, a WBS is not always available. In these cases, more planning must be done in order to identify project activities clearly.

Resources to perform a project are most interchangeable before the project begins. Once resources have been locked into budgets, with organization and manpower allocations, trading them off can be very expensive. A schedule should not be approved until resources have been initially allocated to the tasks at hand, analyzed and leveled to their most efficient use. Computer software tools, which will be discussed later in Chapter 8, help to level resources.

2.2 SCHEDULE STEPS

- Create a rough master schedule based on cost, schedule and performance risk;

- Create rough detailed implementing schedules; again, based on program risk; and

- Iterate master and detailed schedules until proper balance is achieved.

2.3 NEAR-TERM AND FAR-TERM (ROLLING WAVE) SCHEDULING

Near-term scheduling can and should be accomplished in sufficient detail to support management at each level. Far-term, or rolling-wave, scheduling will be less precise, accounting for the alternative paths which the program may take.

As the program approaches each phase, the schedule for that phase will be fleshed out with more detailed schedule information. The schedule for the out-year phases will be adjusted based on the most current information. However, this should not be taken as a license to make easy changes in the schedule. Every effort should be made to maintain the original schedule.

2.4 TRADE-OFFS

There is always a trade-off between cost, schedule and performance, and within each of these, there is also the risk factor. Cost includes all resources: people, money,

equipment and facilities. Performance includes quality and the supportability parameters.

The best schedule is the one that supports the best trade-off between these competing demands.

2.5 DURATION ESTIMATION METHODS

- Analogy – Based on experience of similar programs.

- Parametric Estimating – Based on development of an estimating relationship, i.e., formula.

- Bottoms-up Aggregation – Zero-based build of schedule requirements.

2.6 SOURCES OF SCHEDULING INFORMATION

- Previous Experience – Lessons learned from own successes and failures.

- Functional and Technical Experts – Advice from successful practitioners.

- Other System Requirements

  — PPBS is Calendar Year driven events.

  — Requirements Generation System is user/customer input on when product or system required.

- Other Programs – Relate to analogy method of estimating duration.

- Regulations, Directives and Guidance – Required reviews and milestones.

2.7 SCHEDULE ADJUSTMENTS

- Crashing a Network – Reducing activity times by spending more money for resources.

- Resource Adjustments – Changes in resource funding and/or personnel levels; Congressional, Office of the Secretary of Defense, component generated.

- New Information – Technology, threat changes, test failures and successes.

2.8 SUMMARY

The roots of successful scheduling lie in the WBS. The WBS represents the project and its parts. It is divided into a sufficient number of levels to allow each task to be specified in terms of resources — such as personnel, equipment, facilities — and time. In addition, the precedence relationships between the tasks are specified, as milestones, or deliverables such as tests, reports and receipt of equipment needed for the project to proceed.

The network can be created on a computer or by the use of labels or batches of paper posted on a whiteboard. Although the latter method may appear overly simple, the payoff is that all team members who are contributing to the project plan can easily see the growth of the plan and the task interrelationships.

With this information in place, one can schedule the project. Schedules with appropriate detail are then developed for the different levels of management.

3

GANTT CHARTS

3.1 SCHEDULING WITH GANTT CHARTS

Henry L. Gantt contributed to the technology of scheduling in the early years of the 20th Century with an easy-to-use bar chart method that communicated visually, without confusion. Gantt's "daily balance chart" was a significant breakthrough. Suddenly, the overall program schedule could be seen at a glance, and the start/stop times of the program's individual components. A Gantt chart can be superimposed with ease on a calendar. Then, by shading in each bar as progress is made, the manager can easily measure actual progress against the schedule. An example of a simple bar chart is shown in Figure 3-1.

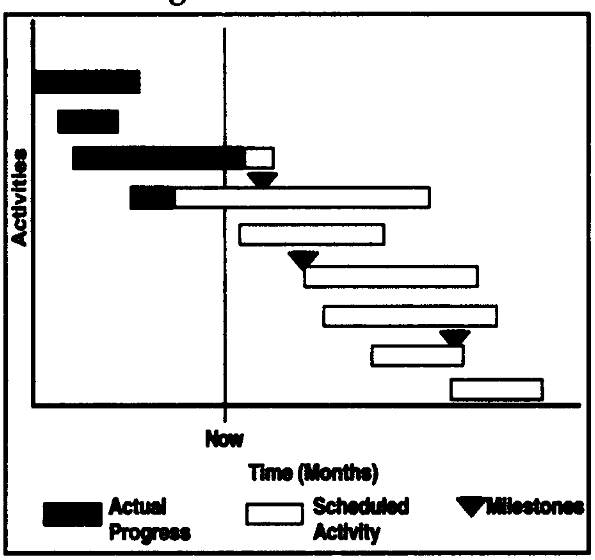


Figure 3-1. Gantt (Bar) Chart

For the past 70 years, Gantt charting has been one of the best ways to schedule activities, for the following reasons:

- Effective communication;
- Easy to prepare and use;
- Show key activities with specific start and completion time (schedule and actual); and
- Relate schedules to calendar dates and to days or weeks from program start to completion.

Figure 3-1 shows that milestones may be added to Gantt charts to display significant events. In fact, it may be appropriate to show a number of milestones associated with a single bar.

A shortcoming of Gantt charts is the limited information they portray. Dependency and other interrelationships among activities are difficult to display because Gantt charts handle a limited degree of complexity. Figure 3-2 shows how a Gantt chart can provide a clear, but limited, picture of dependencies and progress. The Gantt chart can present a history of changes and rescheduling occurring on a program; however, this is done more frequently on milestone charts, which will be discussed in the next chapter.

Modern computer scheduling programs which show dependencies of activities in Gantt chart format are being developed. These programs will be discussed in Chapter 8.

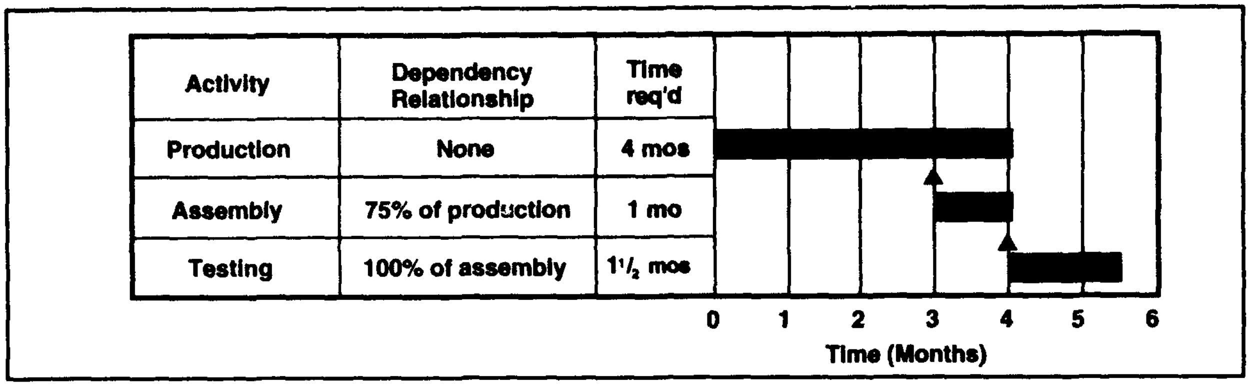


Figure 3-2. Gantt Chart Showing Dependency

3.2 SUMMARY

As a scheduling tool, the Gantt chart is simple, communicates well, and displays calendar anu significant program dates. Because of its simplicity and ease of interpretation, it is a particularly good tool for communicating to higher management when information must be presented quickly and efficiently. However, the chart is limited in the degree of detail and interrelationships it can portray.

Table 3-1. Pros and Cons of Gantt Charts

PROS:

- Easy to understand, update and prepare
- Inexpensive preparation
- Reliable estimates can be developed when the work is repetitive and when the product is easy to measure quantitatively

CONS:

- Only as reliable as the estimates on which they are based: looking at the chart doesn't indicate which estimates are the most reliable
- Hard to visualize activity dependencies in complex projects. (This is changing with the advent of modern computer scheduling programs.)
- Doesn't allow quick or easy exploration of the consequences of alternative actions

4

MILESTONE CHARTS

4.1 MILESTONE SCHEDULING

Milestone charts are event-oriented, whereas Gantt charts are activity-oriented. For a particular program, a set of key events, or milestones, are selected. A milestone is a scheduled event that will occur when a particular activity is started or completed. Milestones are selected from a program's Acquisition Strategy Report (ASR) and visually depicted on the Program Structure or Schedule; see DoD 5000.2M for details. By reviewing the status of key milestones, one can assess quickly the overall program status.

Although milestone charts can present more information than bar charts, they share one important drawback: they invite surprises. A surprise can occur when the number of displayed milestones is too limited or when interdependencies are not portrayed. The result may be that the PM does not know the status of a key event until it occurs, or until it fails to occur when scheduled. A well-conceived milestone status report can provide early warning of a potential problem. Early problem recognition is a key to successful program management.

The milestone scheduling technique uses a symbology consisting of arrows and diamonds, or similar designators, to show originally planned event dates and the changed dates. Figure 4-1 shows symbols used by the Air Force Material Command's Electronic Systems Center (ESC) and the meaning of combinations of the symbols. Program management's scheduling software often has unique symbology to designate activities and milestones which differs somewhat from the Air Force symbology. Any symbol can be used; mechanics are not as important as principles.

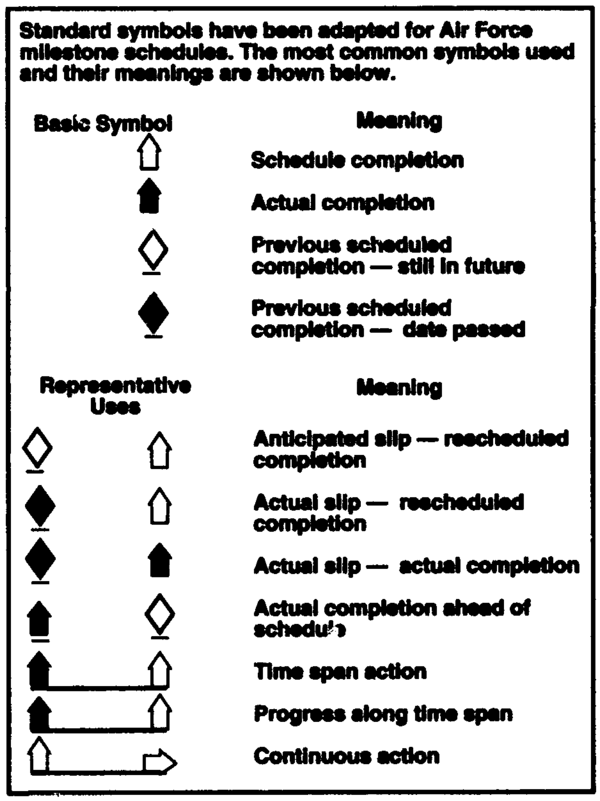


Figure 4-1. Milestone Symbols

Figure 4-2 is an example of a milestone chart. Arrows are used to show rescheduled events, while diamonds indicate the originally planned schedule. As a result, the milestone schedule improves on the Gantt chart by retaining the baseline dates, while incorporating changes in planned future events.

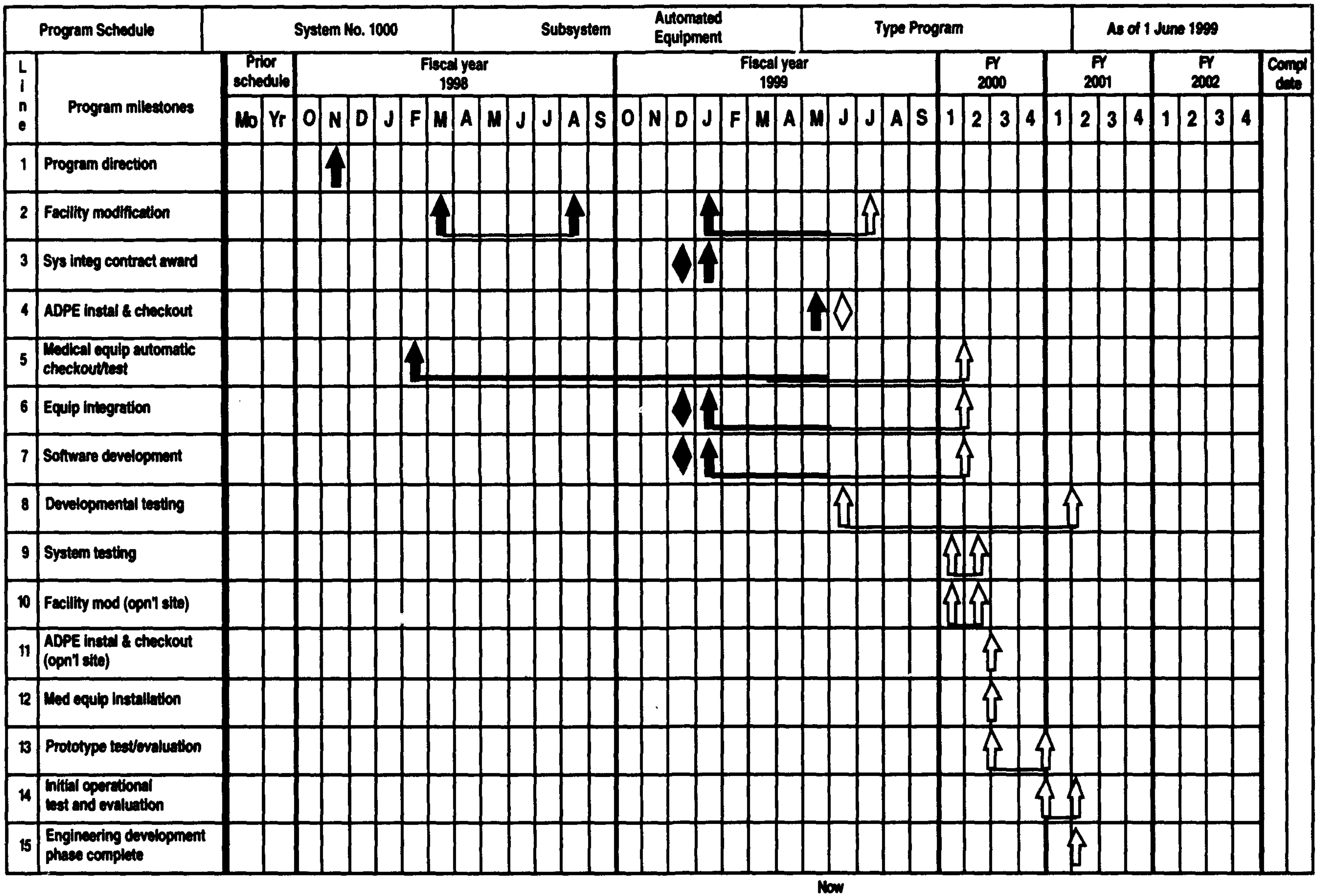


Figure 4-2. Milestone Chart

The milestone chart records the manager's assessment. For example, a manager might reasonably predict that a one-month slip in the start of software development will probably result in a several-month slip in completing the engineering and manufacturing development phase. The milestone chart does not provide the assessment; the manager's experience does. This is the key to understanding the use of milestone charts. Unless the activity and interrelationships of milestones are understood, the chart tells only what has happened and what is yet to happen. However, by coupling the information on what has happened with the manager's experience and knowledge, the PM can predict more accurately what will occur in the future.

The milestone scheduling technique shows what is scheduled, what has happened and changes in plans. The technique is not as useful for forecasting schedule changes as are the network and line-of-balance techniques discussed in later chapters.

4.2 STRENGTHS

Like the Gantt chart, the milestone chart is an effective method of communication. The symbology is relatively standard and simple to use. The chart presents actual progress against a baseline plan and displays changes in plans. The mechanics of constructing a milestone chart are relatively easy. Many defense contractors use milestone charts extensively, and the charts have become a mainstay of program management.

4.3 LIMITATIONS

As with bar charting, a major weakness of milestone charting is the inability of the chart to clearly show interdependencies and the interaction among activities. This may be especially true if the chart is prepared manually. If a PM focuses on a relatively simple milestone format, he/she may lose sight of the complexity of the relationships among various program tasks.

When milestone charts are used on complex programs, they are usually the product of network analysis. If the milestone chart is provided by a computer software application and the use of network analysis, it may also show activity dependency. Milestone chart preparation is relatively simple, but developing and analyzing the information going into the charts can be time-consuming. A controlled flow of accurate, timely and appropriate information to assist in constructing milestone charts is important.

4.4 SUMMARY

Milestone charting represents a simple and effective means for displaying the actual versus the planned progress of a program, and for showing schedule changes that have occurred. These charts emphasize start and completion dates rather than the activities that take place between these dates.

Milestone charts generated manually display very limited dependency information. However, dependencies may be depicted in some software scheduling applications.

5

NETWORK SCHEDULING

"Network scheduling is a prime example of the value of graphic art to management. The visual display has obvious worth in direct communication between program managers, supervisors, and workers; all of them see the same picture of anticipated action and they can discuss it in the well-defined terms associated with networks."
— James L. Riggs and A. James Kalbaugh[1]

The shortcomings of Gantt and milestone charts gave rise to network scheduling in the 1950s. The network techniques provide a method of graphically displaying information that cannot be presented with bars or milestones.

To analyze a program, it is separated into activities. Each activity is based on a particular undertaking and is defined by a distinct start and completion point. Network scheduling provides a method of finding the longest, most time-consuming path. This gives the PM two important tools. First, he/she is able to estimate more accurately the total time from program start to completion. Second, by being able to identify items on the critical (or longest) path, as opposed to less critical tasks, the PM is able to analyze and prioritize problems as they arise.

5.1 PROGRAM EVALUATION AND REVIEW TECHNIQUE

The Program Evaluation and Review Technique (PERT) was developed in 1957 under the sponsorship of the U.S. Navy Special Project Office. The Navy wanted PERT as a management tool for scheduling and controlling the Polaris missile program, which involved 250 prime contractors and more than 9,000 subcontractors. The PM had to keep track of hundreds of thousands of tasks.

PERT helps the PM answer the following questions:

- When is each segment of the program scheduled to begin and end?
- Considering all of the program segments, which segments must be finished on time to avoid missing the scheduled program completion date?
- Can resources be shifted to critical parts of the program (those that must be completed on time) from noncritical parts (those that can be delayed) without affecting the overall scheduled completion date for the program?
- Among the myriad of program tasks, where should management efforts be concentrated at any particular time?

Most activities in a PERT network take a long time to accomplish; therefore, time is usually expressed in days or weeks.

Because PERT was intended to increase a PM's control in situations where time estimates were difficult to make with confidence, time estimates were calculated from

a probability distribution (see Figure 5-1). The developers of PERT chose the beta probability distribution because it could accommodate non-symmetrical situations. They assumed that the probability of an estimate being too optimistic would not be equal to the probability that the same estimate would be too pessimistic. That is, if estimated times could be compared against actual completion times in a number of cases, the variation would look like the curve in Figure 5-1.

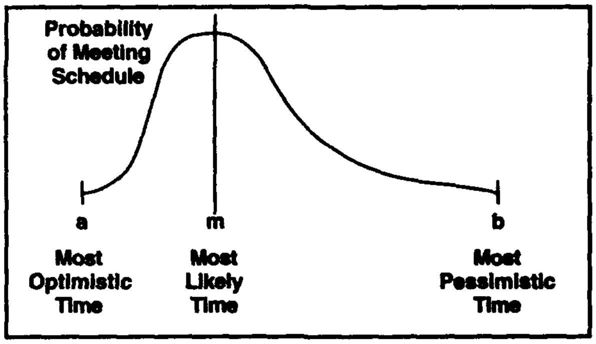


Figure 5-1. Beta Distribution with Symbols Indicating Time Estimates

To calculate the estimated time for any activity, compute the mode of the beta distribution using the mode(m), the most optimistic (a), and most pessimistic (b) times as the basic data points for constructing the distribution. The equation for this calculation is:

$$t_e = \frac{a+4m+b}{6}$$

This is an estimate of the weighted average, or mean time, for an activity.

According to Hugh McCullough, former Polaris project business manager, PERT had a disciplinary effect on the project, which had a 20,000 event network. The successful application of PERT is credited with saving two years in bringing the Polaris missile submarine to combat readiness.

During the next few years, PERT became widely used throughout systems acquisition programs. However, a few years later, the use of PERT declined and, by the 1970s, it was only occasionally employed in defense systems programs. Recently, in the late 1980s and early 1990s, it has again become relatively popular, particularly in the private sector. This resurgence is due in part to the development of PERT software or other networking software programs that can be run on microcomputers.

Why did PERT go through such a rapid rise and then decline? Frequently, it was over-applied. When PERT was combined with cost data or other nonscheduling aspects of program management, it became cumbersome. Department of Defense (DoD) PMs and defense contractors spent immense amounts of time collecting and entering detailed data. As a result, the cost of maintaining PERT systems far outweighed the benefits.

Eventually, DoD and the defense industry returned to simpler techniques like milestone charts and bar charts. However, the private sector continues to make good use of network scheduling in areas such as new product development, construction and major maintenance activities. Defense PMs have also begun to use PERT to get a firmer grip on critical path activities and because software packages make PERT easier to use.

In spite of misuses that have occurred in PERT appliations, the technique can be a very useful tool because it enables the manager to visualize the entire program, see interrelationships and dependencies, and recognize when delays are acceptable. Thus, the manager is better able to assess problems as the program evolves.

In order to apply PERT and similar networking techniques, it is important that following conditions exist:

1. The program must consist of clearly defined activities, each with identifiable start and completion points.

2. The sequence and interrelationships of activities must be determined.

3. When all individual activities are completed, the program is completed.

Many program-oriented industries, such as aerospace, construction and shipbuilding, meet these criteria and use a network scheduling technique. Many defense system programs also meet these criteria, and the judicious use of network scheduling techniques may provide the PM with a useful tool.

5.2 CRITICAL PATH METHOD

The Critical Path Method (CPM) is activity-oriented, concentrating on activity start (Early Start/ES; Late Start/LS) and finish times (Early Finish/EF; Late Finish/LF); whereas PERT is event-oriented, concentrating on early event time (TE) and late event time (TL).

Like PERT, CPM is composed of three phases: planning, scheduling and controlling. Developed in 1957 by J. E. Kelly of Remington-Rand and M. R. Walker of DuPont to aid in scheduling maintenance shutdowns in chemical processing plants, CPM has enjoyed more use than any other network technique.

The CPM technique brings the cost factor more prominently into the scheduling and controlling process than PERT does. When time can be estimated closely and when labor and material costs can be calculated quite accurately early in a program, the CPM technique is superior to PERT. When there is much uncertainty and when control over time outweighs control over costs, PERT is a better technique to use. However, the basic networking principles in PERT and CPM are similar.

In a common version of CPM, two time and cost estimates are given for each activity in the network: the normal estimate and the crash estimate (see Figure 5-2). The normal time estimate approximates the most likely time estimate in PERT; the normal cost is the cost associated with finishing the program in the normal time. The crash time estimate is the time that will be required to finish an activity if a special effort is made to reduce program time to minimum; the crash cost is the cost associated with performing the effort on a crash basis so as to minimize the time to completion.

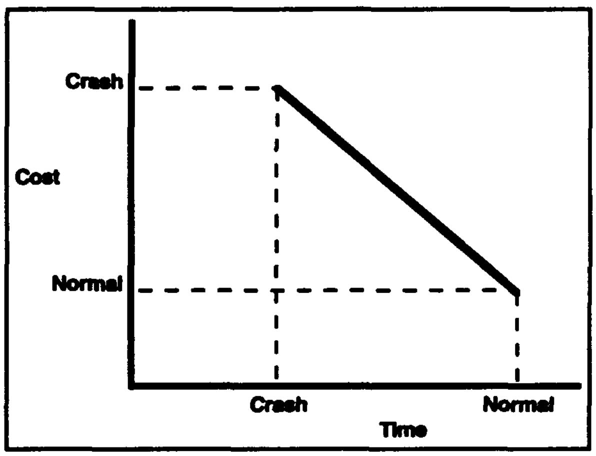


Figure 5-2. CPM Time-Cost Curve

5.3 DEVELOPING A NETWORK

Although CPM and PERT are conceptually similar, symbols and charting techniques vary. Historically, PERT has utilized probability techniques to calculate activity time while CPM generally has not. The following procedures apply to both CPM and PERT.

1. Identify all individual tasks comprising the program.

2. Determine the expected time to complete each activity.[2]

3. Determine precedence and interrelationships existing among the activities.

4. Develop a network diagram presenting these activities in proper sequence and reflecting any dependency relationships. Activities are indicated by lines; events or milestones are indicated by circles. Dependency or sequencing relationships among activities on separate paths can be shown by dotted lines.

5. Complete and annotate the cumulative time required to reach each milestone along the paths, which will indicate the earliest time work can start on the next activity. The final number will indicate total time required to complete a particular path.

6. Identify the critical path. This is the sequence of events, or route, taking the longest time to complete.

7. Starting at the program completion milestone on the right side of the diagram, begin working backward and compute the latest time an activity can start without delaying the overall program. For example, if the total program takes 40 weeks and the final activity requires five weeks, this activity cannot begin later than week 35. For PERT, the difference between the earliest event time and the latest event at each event is the slack time or float. The critical path contains no slack time; i.e., free time. For CPM, the difference between the latest start and earliest start of an activity is also the slack or float.

Figure 5-3 shows a simple network diagram for a computer installation program which will require 20 days to complete. The critical path is F-G; any delay on this path will delay final completion of the program by a corresponding amount. However, a delay of one day can occur along path C-D-E or five days along path A-B-E, and the final program completion date would not be extended.

Critical path programs may be either activity-oriented or event-oriented. This means that the input and output data are associated with either activities or events.

Many CPM programs and a few PERT programs require that events (circles on the diagram) be described in ascending order, as has been done in the following example involving the installation of a computer. However, this is not always done because it inhibits the flexibility of the network.

Another recent improvement in the determination of activity time is the use of learning-curve theory. In 1993, C. Teplitz and J. Amor[3] developed a technique for applying learning curves to predict estimated completion times for a project more accurately. As an example of their technique, a project of building 20 houses was predicted to take 288 days when using experienced workers. The project time was then revised to 384 days by using learning-curve estimates for less-experienced workers. This revised time headed off many of the delays and headaches that would have resulted from a promised 288-day completion date.

5.4 CONVERTING AN UGLY DUCKLING TO A SWAN

Although the traditional CPM technique provides useful scheduling data about a

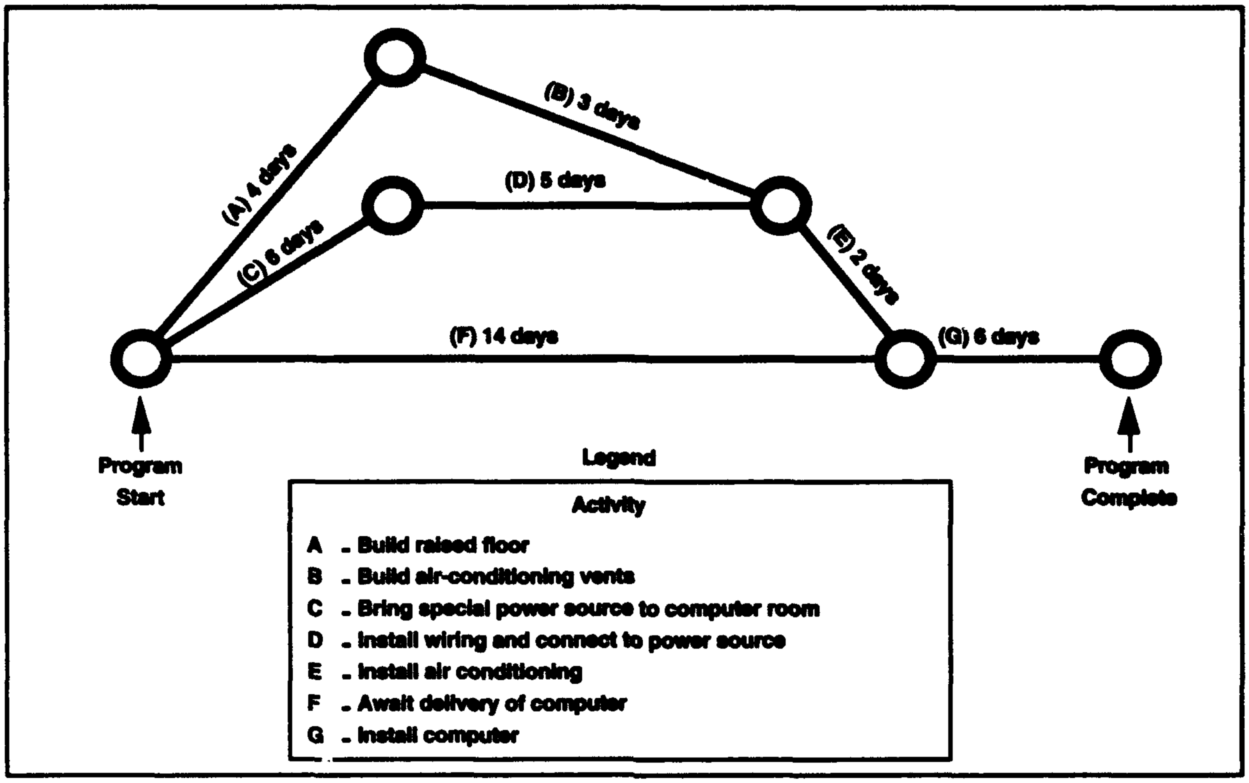


Figure 5-3: Network Diagram for Computer Installation Program

program, it is difficult to draw the chart to match a time or calendar scale. The critical path and slack times can be computed easily, but they are not readily apparent. Also, this technique does not display progress to date. Consequently, a simpler charting technique, sometimes called the Swan network (as opposed to the Ugly Duckling) is useful.

Let's take an Ugly Duckling network (Figure 5-4a) and turn it into a Swan network (Figure 5-4b).

In Figure 5-4a the letters in parenthesis represent activities between the start (S) and completion (C) points. Numbers indicate weeks required for each activity.

In Figure 5-4b, activity A is represented by a horizontal bar four weeks long. Events are represented by vertical lines or "fences"; for example, the fence after B means B must be completed before E and F can begin (the same as in Figure 5-4a). The result is shown in Figure 5-4b.

What does the Swan network show?

- **Critical path.** Time constraints need not be calculated. There are, in fact, two critical paths, B-F-I and C-J-K, which are critical because each has a continuous series of activities and take the same amount of time. There is no slack in either path. Also, the figure has a time scale, which adds greatly to the meaning of the chart.

- **Weeks from start.** Scales for "calendar weeks" and "weeks to completion" can be added. In Figure 5-4b, the program is scheduled for completion after 14 weeks.

- **Slack time.** The network shows where there is slack in the schedule and the extent of that slack. For example, there are only

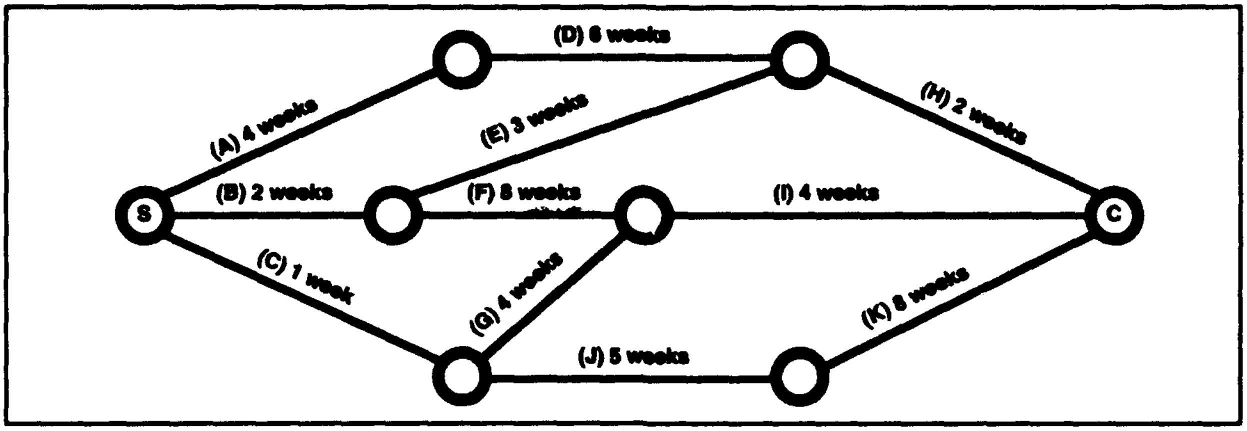


Figure 5-4a. The Ugly Duckling

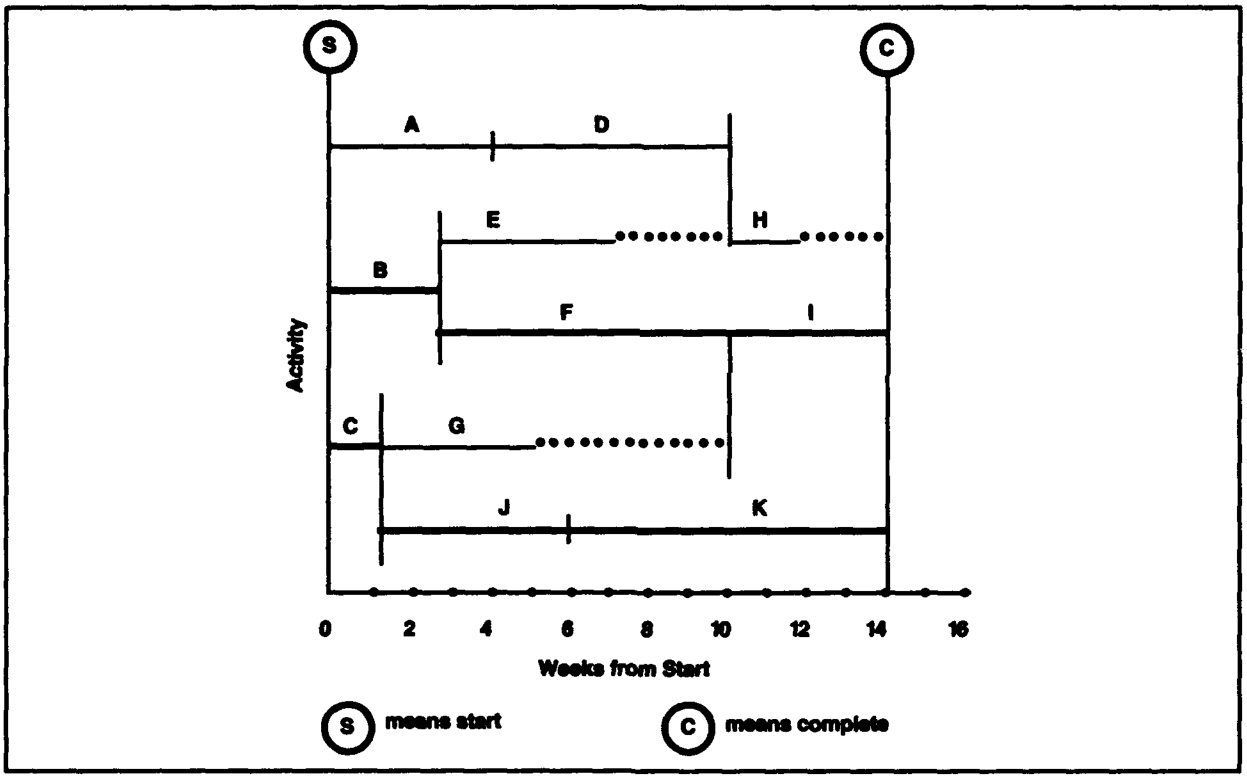


Figure 5-4b. The Swan

two weeks of slack in the A-D-H path. If B-F-I and C-J-K were shortened by more than two weeks, A-D-H would become a critical path. This changing of critical paths is important when conducting "what if " exercises.

The high visibility offered by the Swan network does the following:

- Communicates easily and efficiently;

- Motivates, if the level of detail is sufficient, each person associated with a program activity can see how he/she affects the schedule, and vice versa;

- Gets top-level attention, primarily because it transmits information in an understandable format;

- Makes omissions and errors easier to detect. As an example, one company

discovered by using the Swan network that two test activities on the critical path had been omitted. This was not apparent in the Ugly Duckling network;

- Shows early start, early finish, late start and late finish; and

- Avoids reams of tab runs and printouts, usually provided (but not used) for the Ugly Duckling technique.

5.5 DEVELOPING A SWAN NETWORK

The Swan network can be developed by the following:

- Translating from another network, as shown in the preceding example;

- From a list of the preceding and following events or activities, as in the networking problem that follows;

- From scratch, with the sequencing and time estimating required in originating any network; and

- From milestones.

A "fence" in the Swan network is usually a milestone, such as a review or a major event, regardless of how the network is developed.

Actual progress can be shown in the same way as on a Gantt chart. Shading on each bar indicates progress made. A vertical "now" line shows whether activities are on, ahead of or behind schedule, and by how much.

Now, let's go through an exercise involving network scheduling. Take time to work the problem shown in the following paragraphs.

5.6 NETWORK SCHEDULING PROBLEM

Assume you are a PM. Your objective is to schedule the activities on your program so that one lot of missiles will be assembled and shipped to the test site within 56 days at the least cost. Use any technique with which you feel comfortable. If you're not comfortable with some other technique, use the Swan network.

Proceed in the following manner, using Tables 5-1 and 5-2 provided.

- Using lined tablet paper, lay out the network schedule. This will show the critical path and total number of days required.

- Identify the initial critical path (number of days).

- Using Table 5-2, crash the network by selecting the final critical path and related costs that will ensure completion of the program in 56 days at the least cost.

Some key points:

- Crash only along the critical path.

- When an activity is shortened, one or more new critical paths may emerge. Parallel critical paths increase risk dramatically.

- Generally, least additional cost is the criterion used to select which task to crash, but other considerations (e.g., personnel hours) could be used.

It will probably take about 20 minutes for you to determine the solution. Two "school" solutions are at the back of this book (Appendix B).

Table 5-1. Activities, Dependencies, Times and Costs

ACTIVITY[a]	ACTIVITY DEPENDENCY	TIME (WORK DAYS)	NORMAL COST ($000)
1-2 Fab. Initial Guidance Assemblies	None	12	60
1-3 Control Fabrication	None	24	96
1-4 Rocket Motor Fabrication	None	28	105
1-5 Process Warheads (GFE)	None	16	37.5
2-6 Additional Guidance Assemblies	1-2	20	90
2-3 Guidance Checkout and Sub-Assemblies	1-2	16	120
3-5 G&C Sub-Assemblies	1-3, 2-3	8	70
4-5 Machine Rocket Motors	1-4	12	30
5-6 Missile Assembly	3-5, 4-5, 1-5	6	37.5
6-7 Test	2-6, 5-6	10	62.5
7-8 Ship to Test Site	6-7	8	30

Note: a. Table 5-2 contains "crash" data.

Table 5-2. Activity Time/Cost Relationships

Activity 1-2		Activity 1-3		Activity 1-4		Activity 1-5		Activity 2-6		Activity 2-3	
Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost
10	62.5	22	105	26	110	14	60	18	97.5	14	132.5
		20	117	24	115	12	67.5	16	100	12	150
		18	127	20	142						

Activity 3-5		Activity 4-5		Activity 5-6		Activity 6-7		Activity 7-8	
Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost
*	*	10	35	4	60	*	*	6	60
		8	45						

Note: Crash time is in work days and cost is in thousands of dollars.

Crash costs include normal schedule costs. For example, the Activity 1-2 crash cost ($62.5K) includes the normal schedule cost of $60K.

The activity marked * cannot be "crashed."

5.7 NETWORK SCHEDULING WHEN RESOURCES ARE LIMITED

In the previous discussion, the assumption was that a new activity could start as soon as preceding activities were completed, because sufficient resources were available to perform the work. In practice, however, resources to proceed are not always available.

Let's look at an example to illustrate how this network differs in format from previous networks. First, it uses curved lines for activities, eliminating zero-time activities. Second, it identifies each activity in three

ways: (1) by a letter (A), (B), (C), etc.; (2) by estimated duration of activity (in weeks); and (3) by number of people available to work on the activity based on the manager's estimate at the time the network is prepared (see Figure 5-5).

The network in Figure 5-5 can be shown in another manner (see Figure 5-6). In this network, each activity is plotted on a schedule graph with a horizontal time scale: duration of each activity is represented by the length of that activity's line. Each activity has a letter designation and, in parentheses, number of people assigned to that activity at the time indicated (size of work group). The row across the bottom displays total people scheduled to work each week. Thus, in this example, 5-15 people will be required, depending on the week being scheduled.

Now, let's suppose only nine people are available to work during this nine-week period. What are the alternatives? A personnel loading chart can be produced by

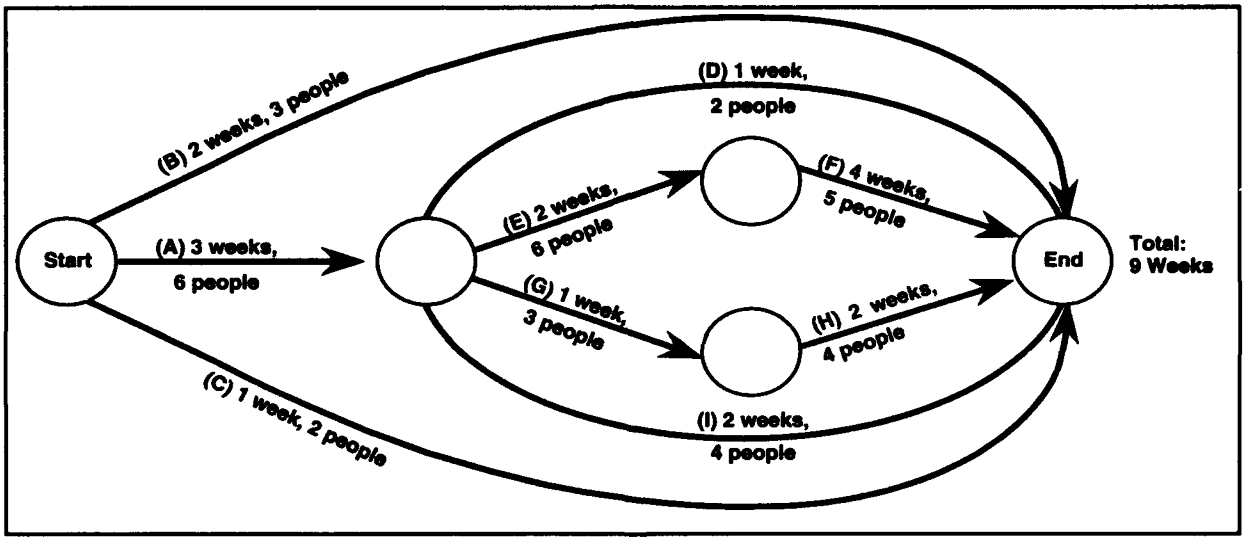


Figure 5-5. Network Illustrating Problem When Resources Are Limited

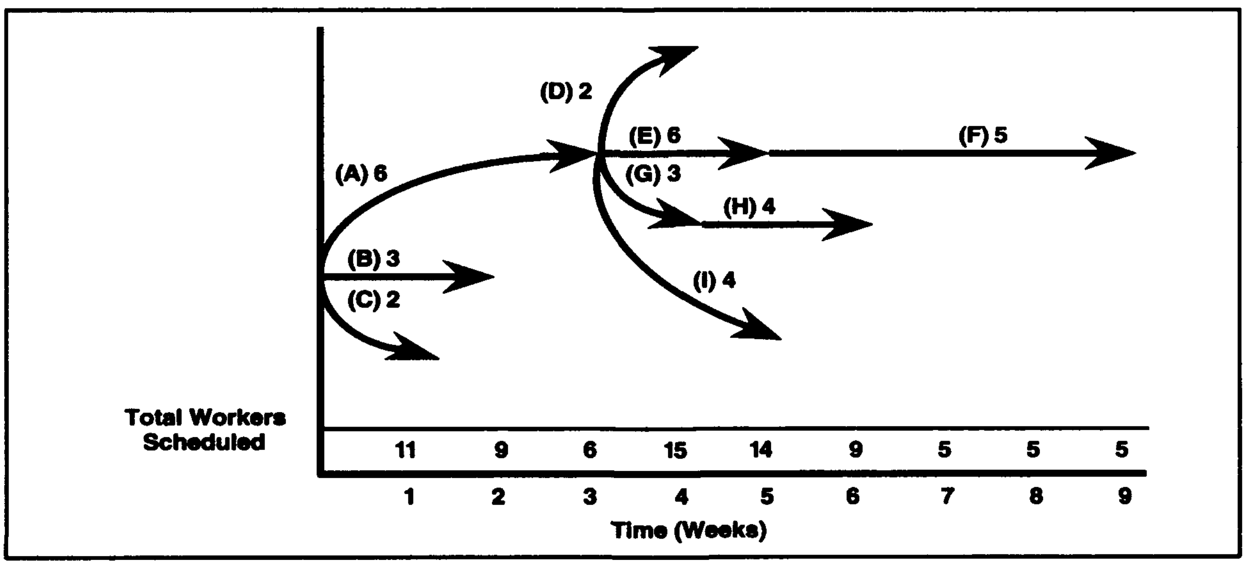


Figure 5-6. Limited Resource Network Plotted on Schedule Graph

plotting the number of people scheduled to work in any week against time (see Figure 5-7).

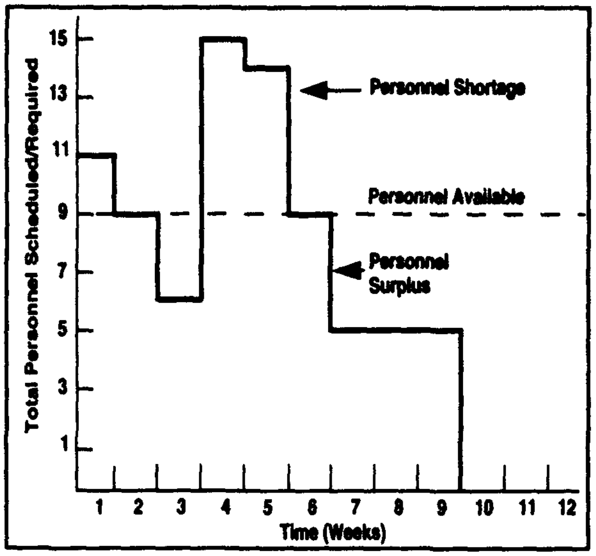


Figure 5-7. Personnel Loading Chart for Schedule Graph

If only nine people are available, the chart shows there will not be sufficient workers during the first, fourth and fifth weeks. There will be sufficient workers to perform the work scheduled during the second and sixth week. During the third, seventh, eighth and ninth weeks, there will be a surplus of workers for the work scheduled. The task becomes one of rearranging the schedule so that, insofar as possible, the peaks and valleys are evened out without scheduling more work than nine people can do. It may not be possible to rearrange the network and still finish the program on time. Under present circumstances, there will not be enough workers to complete the first week's scheduled work on time.

The scheduling problem under consideration can be solved quickly by hand. However, when there are many activities, it becomes very difficult to find the optimum answer, even with a computer. A heuristic program — a collection of rules of thumb that work — should be used to solve this kind of problem.

In the above example, the heuristic approach is to find the activities having the most slack and attempt to delay them as long as possible without delaying completion of the entire program. Delaying the start of activity (C) for two weeks; activities (A) and (B) can begin simultaneously without exceeding the limit of nine workers. Continuing to apply this approach, the revised schedule could look like that shown in Figure 5-8.

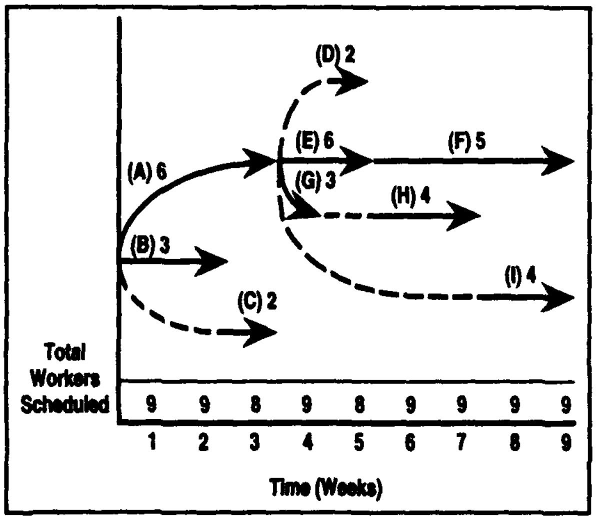


Figure 5-8. Revised Schedule Graph

When an activity is delayed to improve the schedule, the time delay is usually shown by a dotted line. At the end of the third week in the above example, there was an opportunity to delay activities (D), (G) and (I). Activities (D) and (H) were delayed one week and (I) four weeks. Although the example is simple, a perfectly balanced schedule cannot be achieved; however, given this problem most managers would be happy with the extent of this success.

5.8 MULTIPROGRAM CONSIDERATIONS

In his dissertation at Purdue University in 1965, J. H. Mize[4] offered a method for multiprogram control. He developed a noniterative heuristic model that sched-

uled activities for several operating facilities of a multiprogram organization when the objective was to minimize due-date slippage. The outputs from program critical-path analyses became the inputs to the schedule.

Mize took into account the dynamic relationships of activities-to-activities and program-to-program when conflicts arose. His method is generally applicable to any program involving multiple projects which are competing for the same limited resources.

In 1968, L. G. Fendley[5] developed a system based on the concept of assigning the due dates to incoming programs and then sequencing activities of the programs toward meeting the due date. Using the heuristic approach, Fendley concluded that giving priority to the activity with minimum slack-from-due date (his MSF rule) resulted in the best performance. He used the MSF rule to set realistic due dates by determining the amount of slippage that must occur to perform all programs with fixed resources.

In 1970, Mize and L. F. Jordan applied a simulation technique to the scheduling of multiengineering programs. They discovered that a rule based upon a combination of processing time and due dates yielded good results.

All networking concepts can be applied to the scheduling of several programs jointly administered by a single organization. For example, consider the three programs shown in Figure 5-9.

In this example, Program A must be completed before Program B can start. Program C and Program D may begin and be

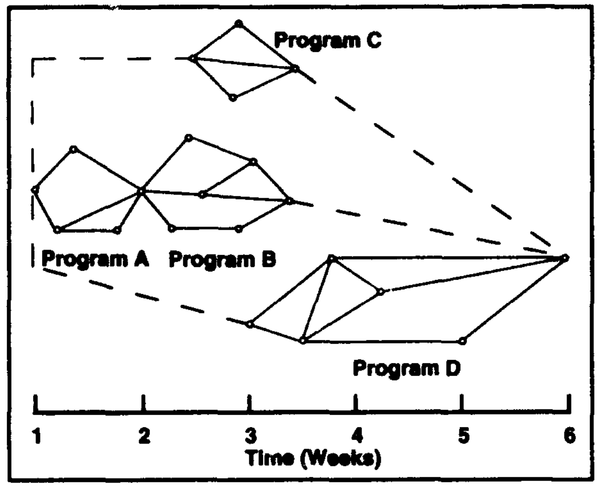


Figure 5-9. A Multiprogram Network

completed any time between Week 1 and Week 6, respectively. Thus, the dotted lines in Figure 5-9 indicate dummy dependencies only and serve to indicate the time span available for all four programs. Duration times could be placed on these dummies to achieve early-start and late-finish program dates, if they exist. The program floats implied by these dummy jobs can be used in the same way that dummy jobs are used in single-program networks. For example, suppose the same resources are used on Programs B and C, but that resource requirements exceed the availabilities because of the simultaneous demands. Figure 5-9 shows that the start of Program C can be delayed until Week 5, so that the resources can be fully employed on Program B. After Program B is completed, the resources can be released for use on Program C. Alternatively, both programs can use the resources at a reduced rate, and both programs will then float out (as long as they do not float beyond Week 6). Whole programs may be cost-expedited. Thus, multiprogram networking techniques are completely analogous to single-program networking techniques.

There is, however, one new aspect in multiprogram scheduling: program pri-

orities. Suppose that Program C (Figure 5-9) is deemed to be the most important program and management wishes to have it start before any other program. In the Resource Allocation and Multi-Project Scheduling (RAMPS) computer algorithm developed in 1963 at C-E-I-R, Inc. by Moshman, Johnson and Larsen,[6] the program priority is used as a weighting factor in scheduling and allocating resources among competing alternative uses in the multiprogram network.

In general, the iterative use of multiprogram-level and program-level network methods provides a medium through which PMs and department-level managers may devise integrated total plans. In 1975, Woodworth and Dane[7] found that multiple networks, submitted by individual PMs, could be merged into a multiprogram network. Several multiprogram network schedules may be developed, using various assumptions about priorities and resources. These alternative schedules may then be examined in staff meetings attended by each PM and the multiprogram manager. The best multiprogram schedule may then be selected based on discussions and criticisms by everyone involved. Of course, several iterations of the schedule may be required between the program and multiprogram level before an acceptable plan is developed.[8]

5.9 SUMMARY

Table 5-3 cites the strengths and weaknesses of network scheduling techniques. Network scheduling techniques such as PERT and CPM are much alike in providing interdependencies, depth of detail, a critical path and slack. The SWAN technique provides simplicity and visibility through the time scales that have been used for many years in bar charts.

The choice between PERT and CPM depends primarily on the type of program and managerial objectives. The PERT method is particularly appropriate if there is considerable uncertainty in program activity times and if it is important to control the program schedule effectively. On the other hand, CPM is particularly appropriate when activity times can be adjusted readily and when it is important to plan an appropriate trade-off between program time and cost.

In reality, differences between current versions of PERT and CPM *are not pronounced*. Most versions of PERT now allow only a single (most likely) estimate of each activity time.

When several small programs are to be scheduled, a multiprogram network might be considered. In this situation, each program can be treated as a separate entity and the entire set of programs diagrammed and handled as one large network. The RAMPS computer program is convenient to apply in this case. Each program in the multiprogram network should be importance-weighted or priority-constrained; this will determine which programs to schedule earlier, which later.

Table 5-3. Pros and Cons of Networking

PROS

- Organize what would otherwise be confusing, thereby allowing managers to make trade-offs and develop alternative plans.
- Essential for activities such as ship overhauls, ship construction and the manufacturing of very complex systems.
- Allow managers to predict shortages and act on them early.
- Once prepared, easy to update and rework.
- Give managers more control over events and schedules.

CONS

- Only as sound as the estimates they are based on.
- Sometimes very hard to portray — too many lines and intersections.
- Complex networks, once sketched out on a large wall chart, tend to become the focus of management attention when, in fact, there may be factors not on the chart that a manager ought to be paying attention to, such as management/labor relations.

6

LINE-OF-BALANCE-TECHNIQUE

"To get understanding and agreement in less time, draw a diagram."

—James T. McCay[1]

6.1 LINE-OF-BALANCE TECHNIQUE

Network scheduling techniques are used primarily in development and other one-time programs. The line-of-balance (LOB) technique is used in repetitive activities such as production. In production programs, LOB charts are particularly useful to balance inventory acquisition with the production process and delivery requirements.

A LOB chart shows which control points need attention now to maintain future delivery schedules. Using the LOB technique, reporting to customers or top management is quick, inexpensive and graphic. Charts used for analysis and troubleshooting are suitable for at-a-glance status reporting. Without a computer-controlled production process, the LOB technique doesn't lend itself readily to day-to-day updating. However, a monthly or weekly check usually keeps the process on schedule.

A LOB technique consists of four elements: (1) objectives of the program, i.e., contract schedule and actual deliveries; (2) production plan in leadtime format; (3) current program status or inventory; and (4) a comparison between where the program is and where it's supposed to be, that is, program inventories versus the LOB. These four elements are shown in Figure 6-1 and described in this chapter.

6.2 OBJECTIVE CHART

The first step in preparing the LOB is to draw the contract delivery schedule on the objective chart (Figure 6-1(A)), which shows cumulative units on the vertical scale and dates of delivery along the horizontal scale. The contract schedule line shows the cumulative units which the contractor is committed to deliver over the life of the program:[2] actual deliveries to date (cumulative) are also shown.

6.3 PRODUCTION PLAN CHART

The second step is to chart the production (or assembly) plan (Figure 6-1(B)). The production plan is a lead-time chart: select only the most meaningful events as control points in developing this chart.

These meaningful events can be given symbols that show whether they involve purchased items, subcontracted parts, or parts and assemblies produced in-house. Assemblies break down into subassemblies, which break down into parts or operations. Thus, one can develop a production plan for any part or level of assembly.

The more steps monitored, the more sensitive and more complicated the chart becomes. Generally, control points on a single chart should be limited to 50. If there are more than 50, subsidiary production plans can be used to feed the top plan. Thus, each chart can be kept simple and easy to understand. The shipping date of subsidiary

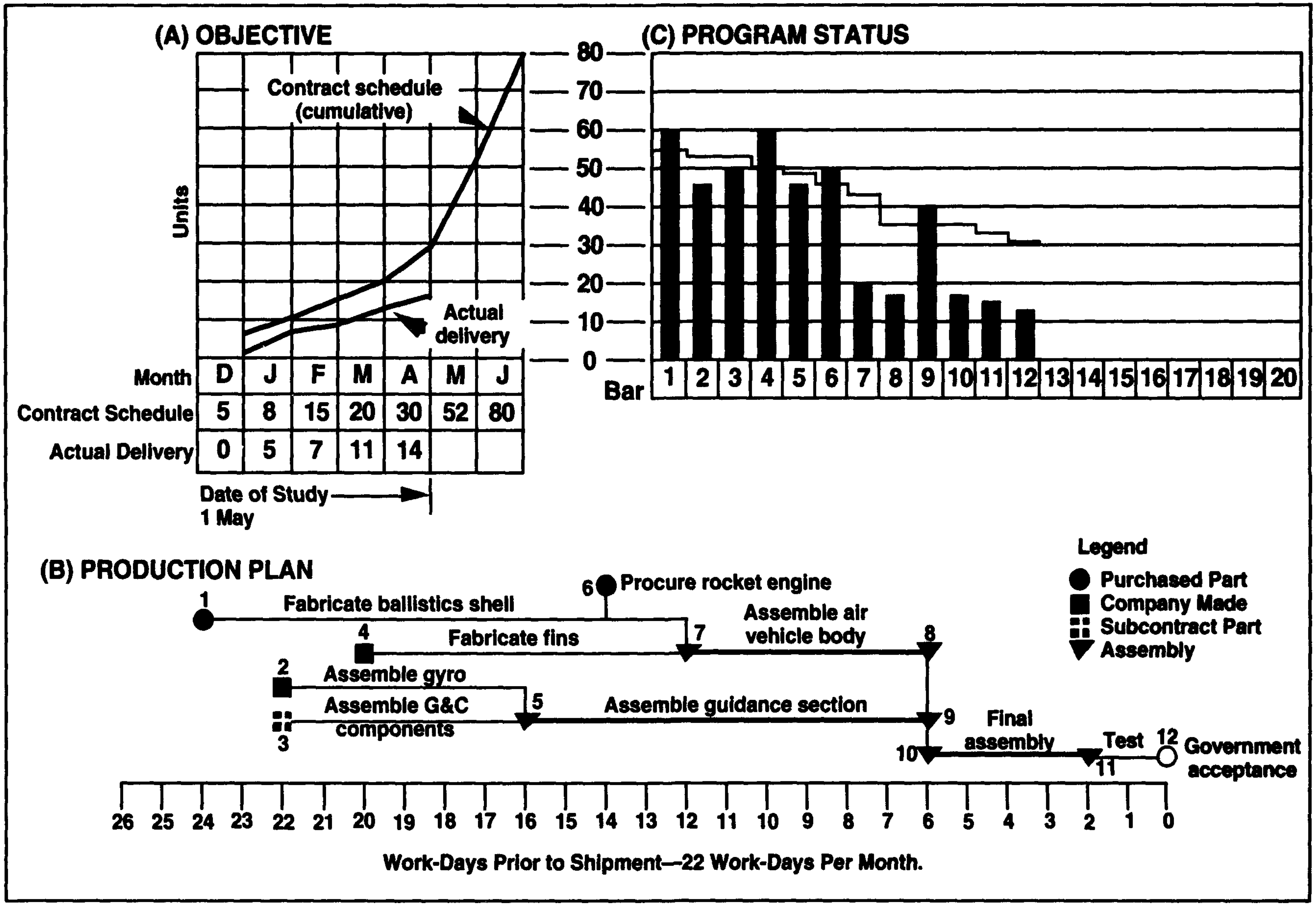


Figure 6-1. Line-of-Balance Charting

charts is the point at which a subprogram must be ready to join the overall schedule.

On the production plan chart, each monitored step is numbered, left to right. Step 1 has the longest lead time; the shipping date is the highest-numbered step. When two steps are done at the same time, they are numbered from top to bottom, such as steps 8, 9, and 10.

The production plan chart shows the interrelationships and the sequence of major steps, as well as lead times required for each step. An understanding of the manufacturing processes involved and sound judgment are required to know which step and how many steps must be monitored. Slack or float times for activities are not considered when plotting the production/lead-time chart; only the estimated time (and latest finish point) for each activity is used.

The 12 control points in the production plan chart used as an example represent key tasks in manufacturing one lot of missiles. The plan indicates that control point (1), fabricate ballistics shell, must begin 24 workdays before 1 January to meet the first scheduled delivery of five units by the end of December (see the objective chart). The lead time for other control points can be related to the scheduled delivery in a similar manner.

In a five-day-week operation, a month generally is recognized as having 22 workdays. Time for in-house transfer and storage must be allowed in addition to the processing time.

6.4 PROGRAM STATUS CHART

To control production, the manager needs monthly status information for each control point. The monthly status inventory is a snapshot of the program status — in this case on 1 May. On the program status chart (Figure 6-1(C)), the bar for control point (12) shows that 14 units of the product have been accepted by the government. The bar for control point (9) shows that 40 units of the guidance section have been assembled. The bar for control point (4) shows that in-house fabrication has begun on 60 fins.

The cumulative numbers of units through every control point can and should be measured monthly. Final deliveries (government acceptances) are shown month-by-month on the objective chart as actual deliveries.

6.5 LINE-OF-BALANCE CHARTING

To analyze how the status of each control point on 1 May will affect future schedules, the LOB has been constructed to represent the number of units that should have passed through each control point (cumulatively) to satisfy the contract delivery schedule. This LOB is superimposed on the status chart bars, which show the status of each control point on a particular date.

The difference between the line and the top of the bar for each control point is the number of units behind or ahead of schedule as of 1 May. Thus, control point (12) is 16 units behind schedule, control point (9) is 5 units ahead of schedule, and control point (7) is 21 units behind schedule. The main impact of control point (7) being behind schedule will be felt in 12 workdays, which is the lead time for control point (7). As of 1 April, an insufficient number of air vehicle components (shell, fins, engine) had passed into the assembly (air vehicle body) phase. This will adversely affect final de-

liveries 12 workdays hence. All other control points can be analyzed in the same way.

To recap, the LOB is constructed in the following manner:

- Select a control point; for example, (7).

- From the production plan/lead-time chart (Figure 6-1(B)), determine the lead time – the time from the control point to shipment point (12 workdays).

- Using this number, determine the date that the unit now at the control point should be completed. (May 1 plus 12 workdays takes you just over halfway through a 22-workday month.)

- Find the point corresponding to this date on the contract schedule line and determine how many units scheduled for completion this represents by moving horizontally from the objective chart to the program status chart (they share the same vertical scale).

- Draw a line on the program status chart (Figure 6-1(C)) at the level (41 units) over control point (7).

- Repeat the above for each control point and connect the horizontal lines over the control points. The resulting line is the LOB, indicating the quantities of units that should have passed through each control point on the date of the study or inventory (1 May) if the contract delivery schedule were being met.

6.6 ANALYSIS

Using the LOB charts in Figure 6-1, management can tell at a glance how actual progress compares with planned progress. Analysis of the charts can pinpoint problem areas. Delays at control point (7) in the example may have been causing final delivery problems throughout the contract. However, the purpose of LOB analysis is not to show what caused the slippage in the shipping date, but to detect potential future problems.

In the example, the government acceptance point is control point (12). The bar doesn't reach the LOB; therefore, deliveries are behind schedule. Control points (10) and (11) are short. However, point (9) is on schedule. Since point (10) depends on points (8) and (9), we know control point (8) is the offender. Both points (7) and (8) are short, but there are more than enough purchased items (engines) at control point (6).

What's the problem with control point (8)? Trace it back to control point (7), which is seriously short. It is obvious that not having enough completed fins is holding up the whole process. Control points (2), (3) and (5) are short, but are not directly responsible for the failure to meet the delivery schedule since (9) is ahead of schedule. Nevertheless shortages at (2), (3), and (5) could soon cause problems at (9). The problem with the fins (7) should be addressed before management attention is devoted to other short operations. The overages at control points (1) and (6) may be examined from the point of view of inventory control. Updating the charts requires a good status-reporting system, which can be mechanized if the program is large and complex.

6.7 SUMMARY

The LOB is a monitoring technique that gives prior warning of problems within a

continuous production process. The key is to catch problems in a production process early; otherwise, the schedule is lose. The LOB technique provides that warning.

Think of the production process as a natural gas pipeline. If a bubble of air gets into the pipeline, it will eventually be carried to the gas users, and the users will find their burners extinguished as the nonflammable air reaches them. The manager of the pipeline company or the natural gas utility, doesn't want their clients to suffer blowouts from air bubbles in their lines. The same holds true for the managers of a continuous production process. Waiting for problems to show up at the end of the line is a mistake. Problems need to be detected when they begin so corrections are faster, before too much damage (to cost, performance or schedule) is done: and production schedules fall too far off contract.

To do LOB, the following is needed: (1) a contract schedule, or objective chart; (2) a production plan or lead-time chart for the production process itself; (3) control points cumulative inventories; and (4) a program status chart on which you will plot your LOB and the cumulative quantities of units that have passed through the control points of the assembly/production process. If the objective and program status charts are given the same vertical scale, the LOB can be plotted graphically from the former to the latter.

Remember that the shape of the LOB will change over time, especially if the production process has a beginning and an end. Remember, too, that LOB charts show where a problem is, but not necessarily why the problem exists or what the solution is.

Table 6-1. Pros and Cons of Line of Balance

PROS

- Points out problems before their impact on finished product deliveries show up, thereby allowing managers to correct problems earlier.
- Allows managers to see, in the middle of a contract, whether they can meet the contract schedule if they continue working as they have been.
- Focuses attention on those production control points where there are problems, which allows a senior manager to pinpoint responsibility for slippages.

CONS

- People working on a project may not grasp what the LOB is measuring.
- Limited to production and/or assembly-type processes.
- Shows only where the problem is, not what it is.
- A monitoring device; not as easy to use as a planning device.

7

TIME MANAGEMENT

It is important that PMs manage time well. PMs are busy people, particularly those in the DoD and defense-related industry. Some managers could be more productive, perhaps as much as 20-40 percent, by applying effective approaches.

This chapter concerns three aspects of time management related to programs:

- PM's time reserve;
- "Now" schedule; and
- Value of time.

7.1 PROGRAM MANAGER'S TIME RESERVE

In contractor performance measurement, much emphasis is placed on "management reserve," the reserve budget controlled by the industry PM. What isn't always recognized is that a time reserve is also needed in order to accommodate unknowns the PM will encounter. However, use of a time reserve should be approached with caution, because members of a program office team may be tempted to fall back on it prematurely.

Literature describing a PM's time reserve is scarce. However, based on discussions with a sampling of managers of both large and small programs, the main aspects of a time reserve are clear.

- Most PMs establish a time reserve of about 10 percent. On a 40-month program, for example, a 4-month time reserve would be established.

- The time reserve must be held closely by the PM. Otherwise, every manager on his/her program may think "I know there's a time reserve; therefore, I don't really have to meet my schedule". The PM may place this reserve under "additional system tests" or another downstream activity. The point is, it shouldn't be visible. (A built-in safety factor between the manufacturing schedule and the delivery schedule is often used.)

- A tough and disciplined approach to meeting the published schedule is required from the start of a program in order to maintain the reserve and, consequently, to meet the program schedule in spite of slippages caused by the unknown unknowns (unk unks) that inevitably arise.

7.2 "NOW" SCHEDULE

There is a direct relationship between time and cost for any activity. This relationship takes into account the people, resources and method used. It also considers the efficiency achieved. Generally, the least costly schedule is the current one. Speeding up the schedule costs more; stretching out the schedule also costs more.

The sum of the direct and indirect costs gives a U-shaped total program cost curve. The optimum schedule for implementing the program is the schedule corresponding to the minimum point on this curve. The

relationship among direct, indirect and total program cost is shown graphically in Figure 7-1.

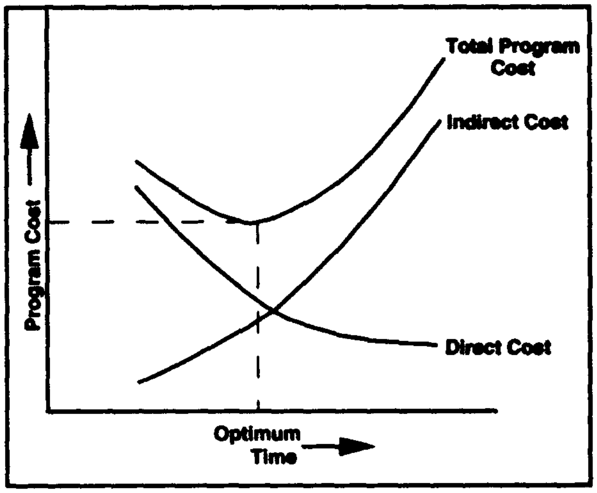


Figure 7-1. Total Cost Analysis for Selecting "Optimum" Program Duration

Because schedule stability affects program costs, which may, in turn, affect technical performance, it is clear that schedule stability has a great deal to do with whether the program meets its cost and technical objectives. Unfortunately, budget constraints and other factors, like changes in quantities (items over which the PM has no control), have often been imposed on a program with the comment, "Do the best you can".

When a schedule must be revised, the superseded schedule is often discarded. If the new schedule is superseded, the process is repeated. However, there is some value in retaining an obsolete schedule. Often, the organization causing a slip in schedule becomes a repeat offender. The principal value of retaining a former schedule lies in being able to hold the offender's feet to the fire, thus making schedule slips less palatable.

The significance of maintaining a stable schedule is becoming more widely recognized. Appendix A describes the development of a master schedule and the importance of maintaining schedule discipline.

7.3 VALUE OF TIME

According to the late John H. Richardson, president of Hughes Aircraft Company, "A basic reason for adopting project (or program) management, when tackling the difficult and unique tasks associated with developing and producing a system, is to eliminate unnecessary delays in accomplishing the job at hand. Time is a resource in systems management, to be treated with indifference or used well like any other resource. For projects not yet in full swing, it is important to recognize that time has economic value, and that we may be taking time too much for granted."[1]

Richardson understood why managers stretched out program schedules.

- Funding could create a problem. In hungry years, the schedule is often stretched because of reduced funding.

- A better product could be developed if it were more thoroughly debugged and tested. However, a system does not really get wrung-out until it is in the user's hands, regardless of advance debugging.

- Cost of concurrency (overlap of development and production) might lead to a decision not to overlap program phases. Such a decision might be popular in many cases, but it could never be tolerated when the pendulum swung toward the importance of time; that is, when top management said "Get the system out the door, never mind what it costs."[2]

Stretched-out schedules incur cost penalties because of inflation, additional engineering changes, and changes in key program management office positions. Another near-term cost is due to the increased

chance that a program will be canceled because of obsolescence or competing technology. Stretch-outs invite cancellation. Also, long schedules with no opportunities for incorporation of improvements are a negative factor when considering a new start.

Delayed decisions increase costs. According to R. W. Peterson, former DuPont executive, "All businessmen are concerned, and properly so, about the long time it takes to move a new development from its inception to a profit status. But frequently forgotten is the fact that a month's delay in the early stages of development is exactly as long as a month's delay in the later stages. While it may seem innocuous to put off a decision for a month or two in the early years of a project (or program) with an uncertain future, that delay may turn out to be just as costly as is procrastination when the final decisions are made. In short, a sense of urgency is essential to decision making in all stages of a new venture, not just the later stages."[3]

The useful life of a defense system must be taken into consideration. Concentration on the system or product often overlooks a key point; whether the buyer obtains value upon delivery. The most costly product is one that appears when it no longer fulfills a useful purpose, even though it has been produced at minimum cost. Each month added to the development and production of a new high-technology system or product tends to reduce by one month the operational life of the system or product.

In spite of the 10-20 percent cost premium that may be paid for tight scheduling (as compared to orderly but stretched-out scheduling), the resulting longer operational life may provide greater economic value. This is looking at time only from the viewpoint of economics; i.e., acquisition cost per year of operational availability. Another way of looking at time is that defense system availability is survival insurance.

Consideration of alternative plans and schedules will also help; e.g., if event so-and-so occurs, proceed with plan "A"; if event such-and-such occurs, proceed with plan "B" and so on. Anticipation and preparation for most-likely events, along with the tools described, and coupled with effective communication of the plans, can change the management style from crisis management to skillful management.

7.4 SUMMARY

Planning and scheduling can do much to prevent running out of time and having to make the least desirable decision because of lack of time. Establishing a time reserve and a "now" schedule, and recognizing the value of time in decision making all contribute to the manager's repertoire of good tools.

Sir Jeffrey Quill, manager of the British Spitfire Development Program, commented during a visit to DSMC that; "After 1935, costs weren't particularly important. What mattered was time. We worked three shifts a day. Everything was time. Quantity and time. It turned out that we probably produced at the lowest cost, too; but the emphasis was on time."

8

AUTOMATED PLANNING, SCHEDULING AND CONTROL

A PM must be successful in managing all aspects of the program. Projects must be defined: human resources, materials and budgets must be scheduled to complete the projects. Work in progress must be tracked. Status reports of progress and variances to the plan must be developed in order to revise schedules, budgets and work assignments. Today, there are numerous automated applications available to assist with the chores of achieving system performance in a timely manner within budget.

8.1 BACKGROUND

Managers of the Navy Polaris Submarine Program during the 1950s, using mainframe computers, first proved to the DoD that automation would play a major role in program management. These PMs recognized the benefits of automation when applied to the decision-making process and as a planning and control tool. However, it was a very costly process, involving significant time for implementation. At that time, automation was used as a project management tool only on very large programs.

Today, as predicted by the late Admiral Grace Hopper on her many visits to DSMC, automation has made a profound impact on the processes of program management. The microcomputer has multiplied the capabilities and productivity of each member of the program management team. Hundreds of software applications are able to provide PMs with automated scheduling tools and project management capabilities. Most of these applications are commercial packages that can be purchased off-the-shelf at most computer stores or from the General Services Administration (GSA) approved contract schedules. The services have also developed, in-house or through support contractors, numerous applications tailored to acquisition management. Some have shells or templates to organize projects, while others may serve as automated listings of pertinent tasks to be completed over the life cycle of the program or project.

8.2 REQUIREMENTS DEFINITION

The decision about which project management software applications(s) to buy should only be made following a careful understanding of the need for such a dynamic product. The PM must review the types of projects to be managed and the functional people who will interface with the acquisition environment and use the software. An accurate analysis of the need will provide a stronger foundation for successful selection of the "right" program to meet that need. A clear definition of the requirement will assist in narrowing down the software alternatives, which vary significantly in price and capability. Various criteria must be established to measure the impact upon cost, schedule, performance and suitability when deciding which software to buy.

8.3 NATURE OF PROGRAMS/ PROJECTS

The fundamental goal of program management is to achieve success in developing and fielding a system that meets the performance requirements of the user, when needed and within affordable cost limits. This is accomplished through the optimization of resource constraints, time and relationships among tasks. Some programs or projects may be categorized as resource-constrained, where the schedule depends more on the availability of resources, while others may be event-driven, *where the schedule depends more on the* tasks and their interdependencies. Schedule risk can be optimized through the concurrent scheduling of activities that have less dependency upon sequenced completion. Schedule risk can also be traded off with cost by reducing the time required to complete those activities on the critical path, thus accelerating completion of the entire project.

According to Danek Bienkowski,[1] author of "Selecting and Implementing Project Management Software", *Journal of Information Systems Management*, Fall 1988, resource-constrained and time-constrained projects should be managed differently, since each requires different tools. Bienkowski said that resource-constrained projects require the Gantt chart for primary emphasis, with the PERT network used as support, whereas time-constrained projects are effectively managed using PERT networks primarily, with Gantt charts in the support role. He also pointed out that it is important to remember this distinction when selecting project management software, because some packages are Gantt-oriented while others are PERT-oriented. Some commercial software packages have strong resource features while others lack this advantage.

When choosing a software package, attention should also be given to whether or not the agencies or organization associated with the project are already using a project management package and if compatibility with that software would be necessary. A cost-benefit analysis of compatibility is a useful approach to addressing this issue.

8.4 SIZE OF THE PROGRAM/ PROJECT

The size and complexity of the program/ project is another major criterion that should be used in selecting a software package. How many tasks are required to complete the project? There may be fewer than a hundred, or perhaps thousands must be tracked. Some commercial packages can track only several hundred activities, while others may be unlimited except for your disk memory. Some packages will allow assignment of many resources to a project or task while others may not.

Similar importance should be placed upon consideration of time scales. Many packages will not allow you to schedule less than a day while others will let you break down the program structure to the hour level. Other time concerns may be considered, such as the maximum duration allowed for a task and the maximum project length in time; e.g., 100 years.

8.5 ADVANCED FEATURES

Today, project management software programs are able to offer open database connectivity, which allows users to link their projects with other databases. This permits rapid updates of project data, such as

activity identification and durations, availability of personnel and their wages, and other costs associated with each work package. Larger packages enable the user to load and access multiple projects in order to share common resource pools and automatically level resource assignments across all projects.

8.6 COST

Generally, software decision criteria will not be complete without consideration of cost. The commercial packages vary in price from less than a hundred dollars to thousands of dollars. The cost of acquisition is a particularly important consideration when a large number of the software packages is required to support many program management team members.

The capability of the package to handle cost within the project is also an essential performance consideration. Some programs do an earned-value calculation and complete a cost distribution or cash flow analysis. Less complex programs provide for the accounting of costs as a fixed amount charged to a task or activity. More capable programs allow the cost to be accrued from the scheduled use of resources as actuals are entered into the program.

8.7 REPORTS AND DISPLAYS

The reports generated within the software may be one of the most essential considerations in selecting a commercial package. Displays of charts, networks and other presentations should be considered among the primary criteria since they readily determine whether or not a package meets minimum requirements to assist the PM in managing a project successfully. Figure 8-1 shows an example of a Gantt chart produced as a standard display from a commercial package. It provides a summary of the activities, the total daily resource allocation for identified resources, and the typical horizontal lines in proportion to time.

Today, many of the software packages provide multiple views of the project. While many have separate displays, many more provide for combined displays, such as the ability to view simultaneously the task list, planned and actual activities in a Gantt time-scaled horizontal bar chart, and a histogram reflecting cumulative usage of work hours expended. Some packages provide a spreadsheet option associated with each task or activity; thus, program financial sheets can be generated, as well as chart-type reports. Another strong feature pro-

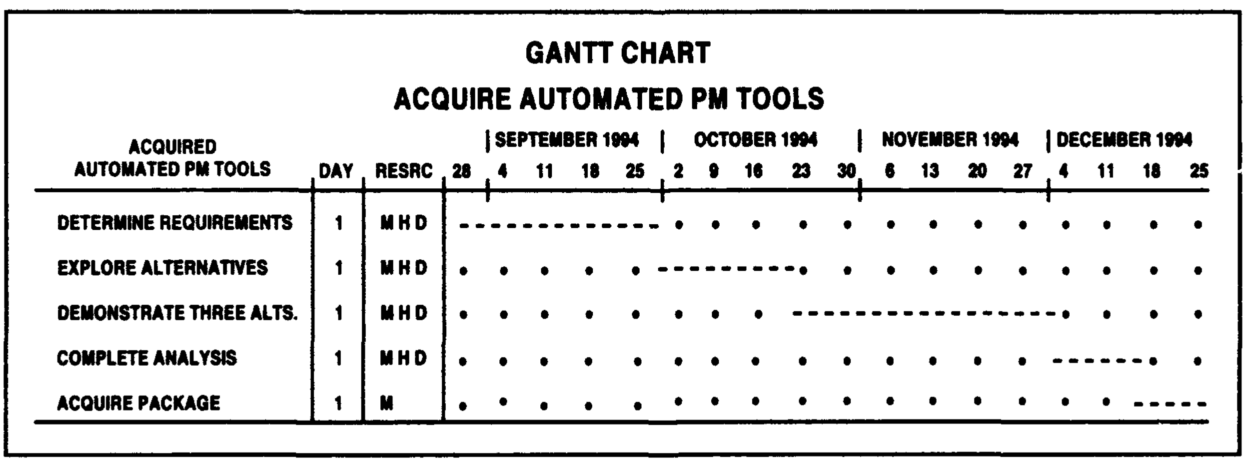


Figure 8-1. Gantt Chart

vided by modern packages is the ability to resource breakdown structure. A combined view of these capabilities generates a responsibility matrix that can be very useful in converting work packages into executable schedules which the PM may rely upon for success.

Figure 8-2 represents a condensed overview of a PERT/CPM network that is a standard display from a commercial package. It provides a symbolic level of detail which is simplified by the legend. The same package also provides expanded presentations; which, include more detailed information such as early start times, latest start times and task duration. Another Network/Gantt commercial package display, used during the planning and execution of DSMC 95 (a curriculum redesign and reorganization project), is shown in Appendix D.

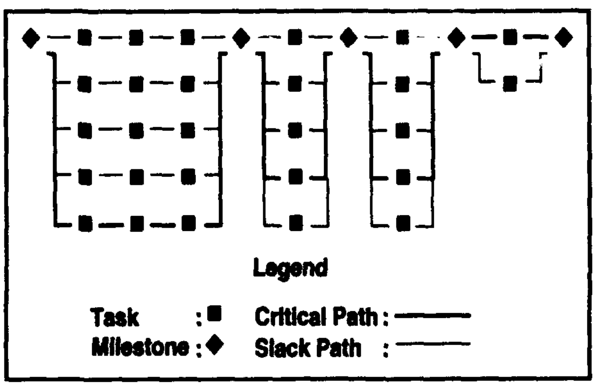


Figure 8-2. Standard Display, PERT/CPM Network

The standard display formats of alternative packages should be reviewed for suitability. The extent to which they can be customized should also be considered. The more powerful programs provide greater flexibility, but are more complicated to use.

8.8 OTHER CONSIDERATIONS

Other considerations may be given a higher priority when selecting program management software packages. Among them are compatibility and support. Commercial packages contain a wide variety of import and export capabilities that enable the manager to interface with other software applications that may already be in use. This interoperability or integration capability may save many dollars through reduced data entry and processing time. There may also be opportunities for savings on support for the package. Producers of these commercial packages offer various levels of support such as training, consulting on-site and by professionally staffed hotlines, newsletters, warranties and promotion of user groups.

8.9 SUMMARY

The selection of appropriate project management software may be a complex process due to the range of capabilities, their mix, and the cost of associated packages. However, if sufficient effort is made upfront to identify the requirements clearly and to examine the alternatives thoroughly, the PM will make a much better decision in ensuring the successful satisfaction of his/her need.

9

RECAPITULATION

The PM is responsible to top management for getting the job done on schedule and within the allowable cost. Today, network-based systems assist the PM in planning, scheduling and controlling the work to be accomplished — often by people in separate organizations not under the manager's direct control. The PM needs a plan that will provide a constant and up-to-date picture that is understood by all.

Scheduling, cost and performance are major elements of concern to the PM, who should be able to blend them to meet program objectives. When selecting a scheduling method, the PM can make a conscious trade-off between the sophisticated methods available and cost.

9.1 PRINCIPAL POINTS

The principal points to be derived from this guide are the following:

- Schedule, time and cost are the three major elements to control in any program. These can be in conflict; therefore, trade-offs may have to be made.

- All programs involve planning, scheduling and controlling. During the planning phase, objectives, organization and resources are determined. During the scheduling phase — the phase with which this guide is concerned — personnel requirements have to be determined, and time to complete the work and the cost have to be estimated. During the control phase, the program's progress in terms of time, cost and performance have to be measured. Necessary corrections have to be made to ensure achievement of the program objectives.

- The activity-oriented Gantt charts are useful when activities are not closely related and the program is relatively small. The chart's value is its ease of preparation and use, along with its ability to show key activities with specific start and completion times.

- The milestone charts, which are event-oriented, will indicate progress by displaying start and completion dates, but may invite surprises because the PM may not know the program status until an event occurs, or fails to occur.

- The network displays how a program can be done by depicting activities and their relationships. The schedule establishes how it is planned by showing the time it takes to get done.

- A network identifies the critical path, slack (time an activity or event can be extended and still be completed on time) and activities needing rescheduling. Activities on the critical path have zero slack and must be completed on time to prevent slippage of the overall program completion date.

- The CPM, a network-based scheduling method, uses a linear time-cost trade-off; i.e., it adds the concept of cost to the

PERT format. If necessary, each activity can be completed in less than normal time by crashing the activity for a given cost.

• The LOB technique of scheduling is effective in manufacturing where a final assembly line is fed by many component lines and delivery of end-units is required at predetermined specified intervals. Effectiveness of LOB is based on the design of the assembly plan.

• Computer programs are available for network-based scheduling. Manual calculations are feasible for small problems like those set forth in this guide; however, computer assistance is almost a necessity for large and complex networks.

• Network-theory assumptions that activities are independent, discrete and predictable are not always appropriate in actual applications. The departure from reality; however, does not normally affect planning and coordinating efforts in critical-path scheduling.

This guide has presented a brief description of the basic elements of program scheduling. These elements constitute one component of the overall management systems in use today.

APPENDIX A
INTEGRATED MASTER SCHEDULE

The master schedule for a program should be a time reference baseline for the program.[1] To do this, it must be kept up-to-date with an approved program for cost, schedule and performance. An approved program is one incorporating an officially approved schedule to achieve approved performance levels within approved cost allocations. Maintenance of the master baseline is a task akin to that inherent in configuration control.

Program changes, whatever the source, start as proposals and, if approved, grow into a firm plan. Eventually, they are incorporated into the program as changes. The question of when to plot these changes is a matter of judgement and should reflect the PM's policy. Each change should be plotted as a proposed or tentative change until approved.

A permanent record of each change should be maintained. If the program schedule slips, it should be documented until documentation no longer serves a useful purpose.

Schedule Discipline

The degree of schedule discipline imposed within the program management office (PMO) can be a major factor in the use of the master schedule. Whenever copies of the master schedule are made, they should be dated and authenticated by the signature of the PM or the appointed schedule manager. Undated and unauthenticated schedules should not be released outside the PMO.

These are simple rules, but they are not practiced by many PMs. Consequently, programs suffer from unauthorized release of schedule information that has not been integrated into the master schedule and has not been approved by the PM.

Program Reviews

The master schedule can be a framework for periodic program reviews within the PMO. If constructed properly, the schedule will illustrate the top-most levels of the program and will be compatible with the program cost/schedule control system reports.

Program reviews can be an excellent forum for resolution of schedule conflicts and the genesis for controlled changes to the schedule from within the PMO. Most key members of the PMO team are present at these reviews; therefore, proposed schedule changes or slips can receive wide dissemination within the organization.

"What If" Exercises

The master schedule can serve as the framework for "what if" exercises imposed on programs from outside the PMO. Schedule changes can be plotted manually by using overlays. Using the same grid coordinates on an overlay allows the PMO team to see, clearly and graphically, the

effect of the compressions or extensions of sub-milestones on the program. It may be even easier (and more productive) for the PMO team to run "what if" exercises on a computerized schedule.

Without a master schedule as a baseline, these exercises can take longer to accomplish and they may overlook important variances from the program's established baseline schedule or plan.

Program Briefings

The master schedule can serve as a baseline for program reviews at higher headquarters and other reviews or briefings outside the PMO. Most programs have key milestones taken from the master schedule and presented in summary form on viewgraphs or slides. If these do not show the detail required to make a point, the time span shown can be reduced to the point where the details become visible.

The master schedule can be transported with the team accomplishing the briefing, but this is not recommended. Extensive handling of the schedule chart can cause unnecessary wear and may result in a need to redraw it. This can be a significant task because the master schedule may be 7' x 10' or as large as 10' x 15'.

Conclusion

The PM should remember the following guidelines:

- Have an integrated schedule prepared in the PMO and maintain control.

- Not overestimate the job. A few smart people on the program team can do amazing things in 7-10 days.

- Not try to get too fancy too fast. Keep the schedule simple until the PMO team has mastered the program and the basics of the process.

- Use the schedule as a basic management tool and make it compatible with the WBS and contract structure.

- Instill discipline in the team. The PM should not allow program schedule changes to leave the PMO until he/she has reviewed and approved them. He/she should be sure every team member works to the same schedule.

- Plan for the unknown. The PM should not approach complex events, like source selection or DAB reviews, with only a viewgraph-level plan.

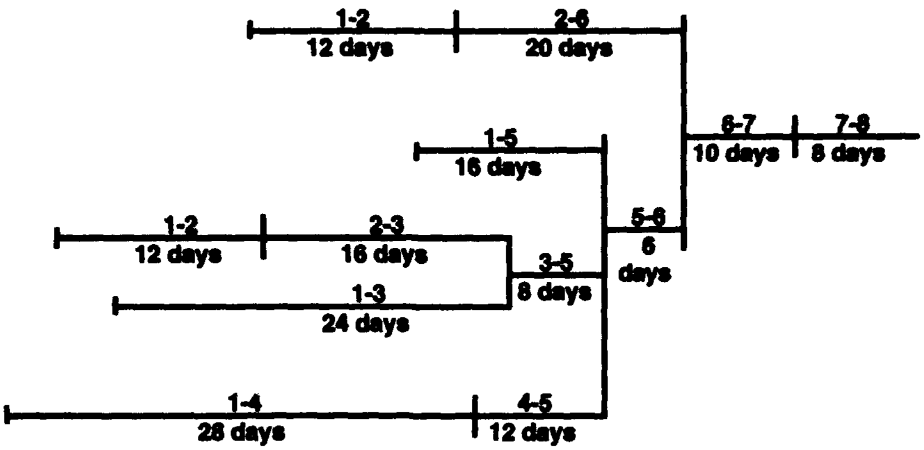
- Not accept an incomplete schedule when assigning the effort to a member of the PMO team. An incomplete schedule could lead to program problems or a cancelled program.

APPENDIX B
NETWORK SCHEDULING PROBLEM

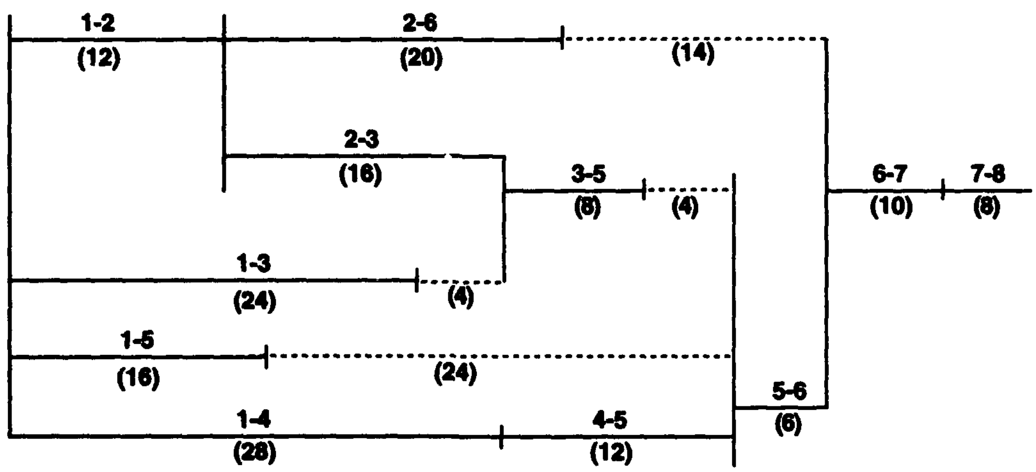
In paragraph 5.6, you were asked to solve a network scheduling problem. Here are two solutions. The first, submitted by CDR Eric Gregory, USN, was computed manually. The second, prepared by LTC Robert Shively, USA, was computer-generated, illustrating what commercially available software can do for the planner and manager. They are referred to as "School" Solution #1 and "School" Solution #2.

"School" Solution #1

Step 1: Work from the right to describe the system (Leadtime Display)



Step 2: Work from the left to set up time lines and critical path (slack shown by dotted lines)



Step 3: Shrink critical path by evaluating alternatives to find lowest cost

Step		Days saved	Cost per day	Added cost
1-4		2	2.5	$5,000
1-4		2	2.5	$5,000
1-2	Dual Critical Path	2	1.25	$2,500
4-5		2	2.50	$5,000
5-6		2	11.25	$22,000
				Total $40,000

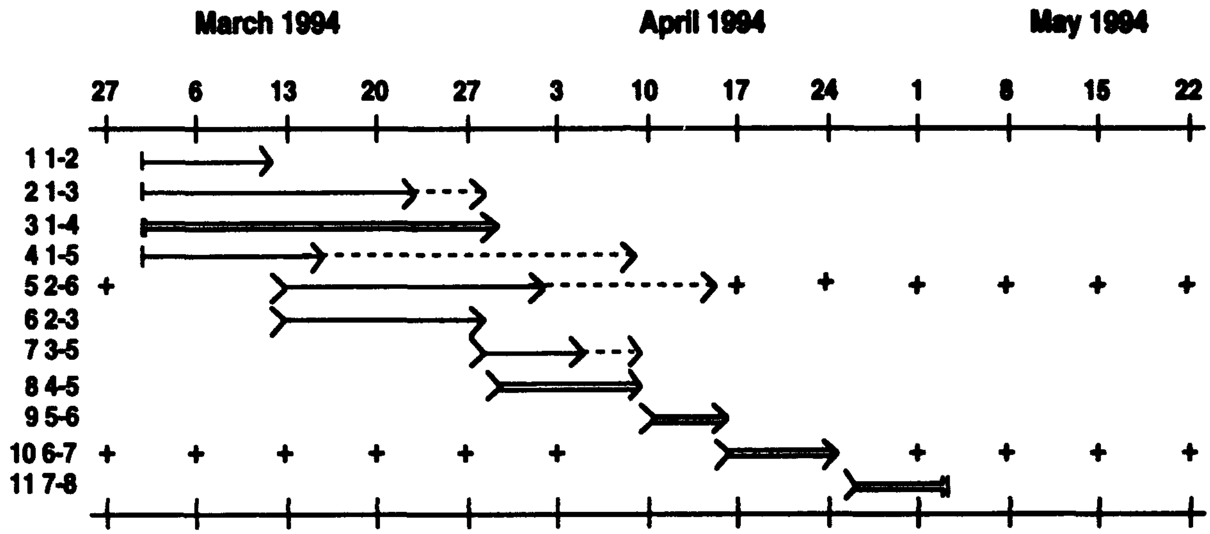
Added cost of "crashing" = $40,000

New total cost of project = $778,500

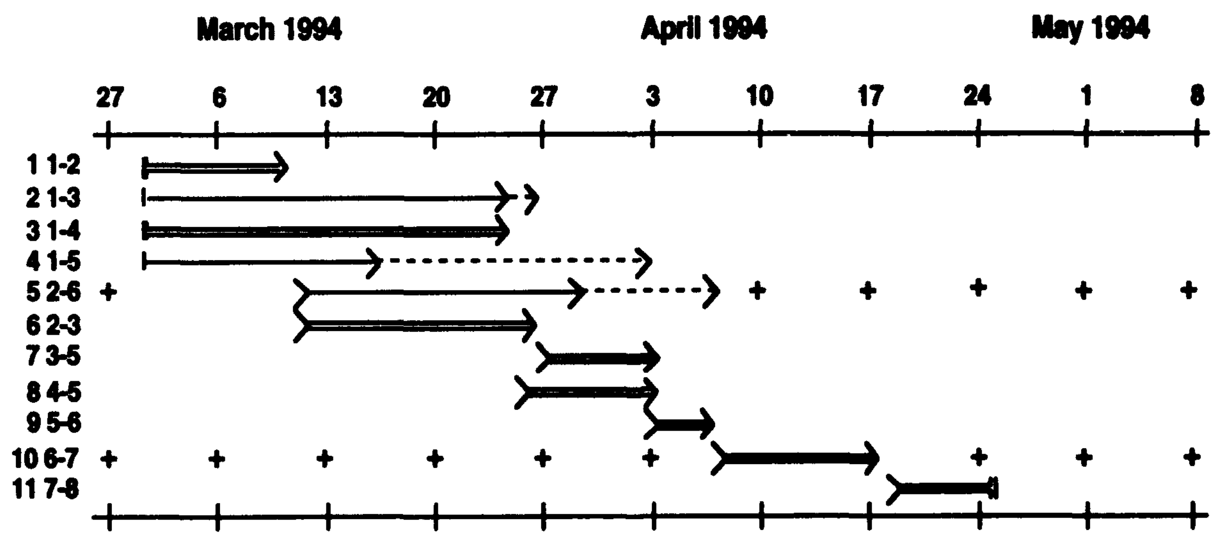
Revised duration = 56 days

"School" Solution #2

Missile Delivery Scheduling Problem (Initial Condition)

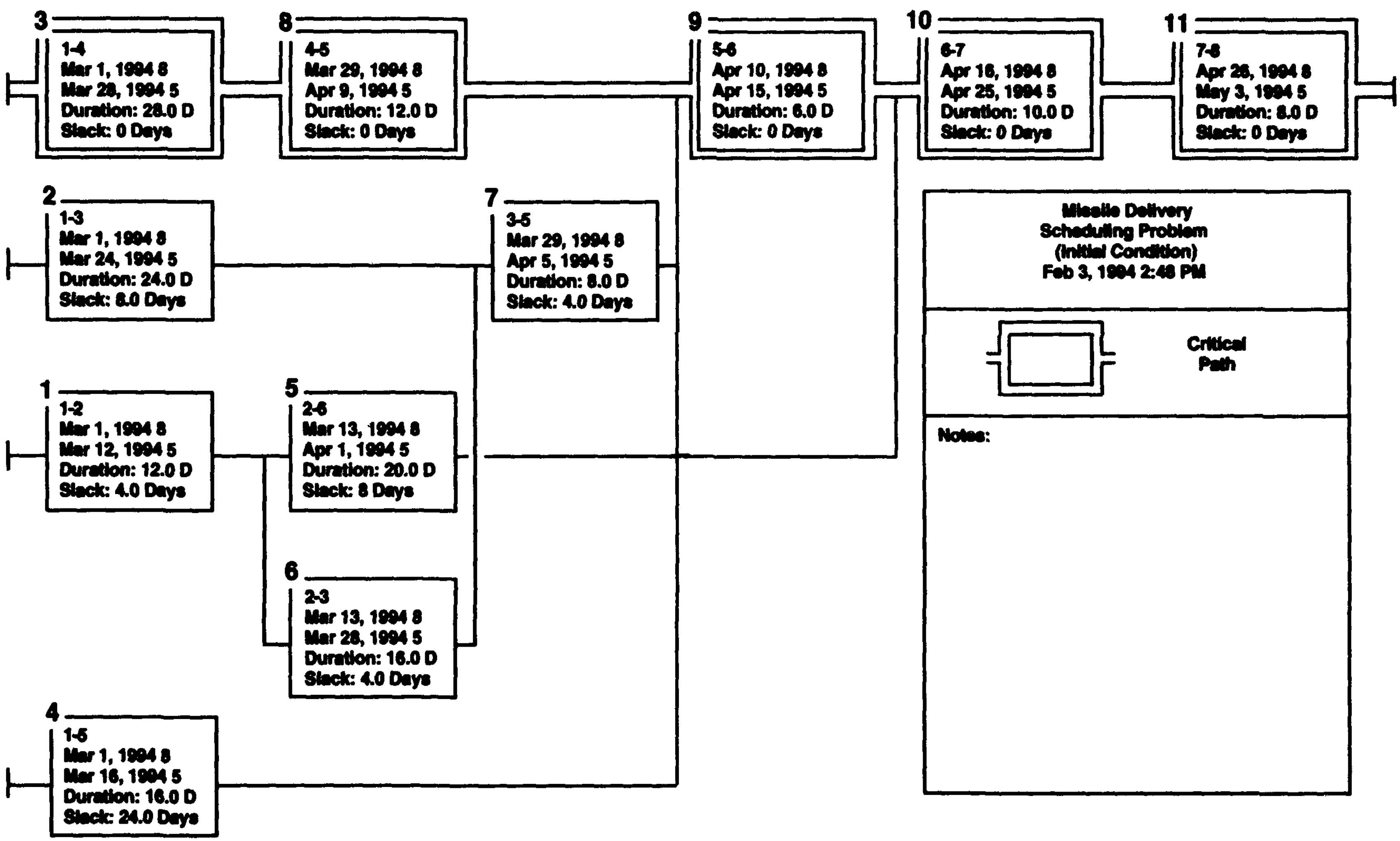


Missile Delivery Scheduling Problem (Revised to 56 days)



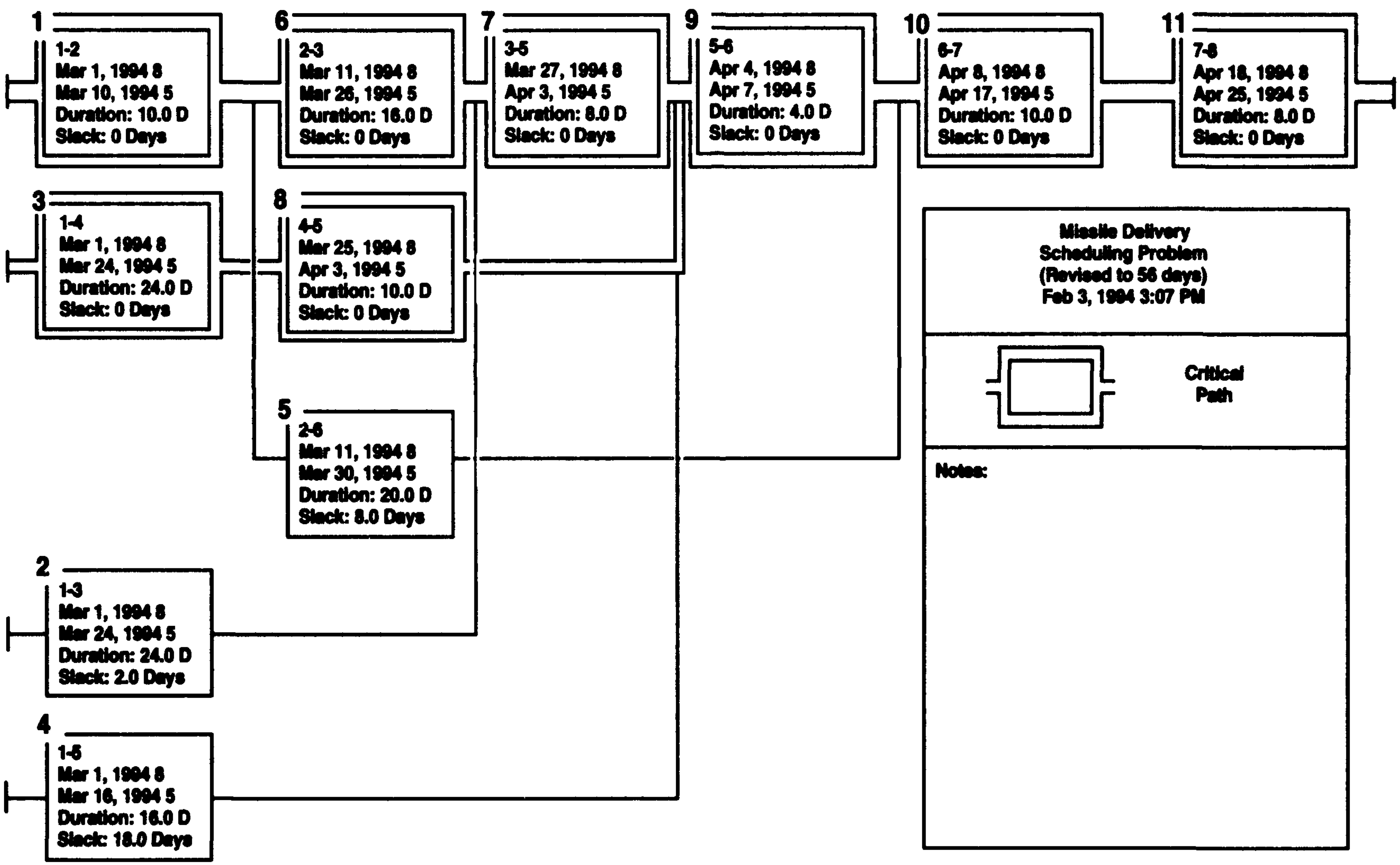
"School" Solution #2 (Continued)

NETWORK DIAGRAM - STARTING



"School" Solution #2 (Continued)

NETWORK DIAGRAM - AFTER CRASHING



"School" Solution #2 (Continued)

Missile Delivery
Scheduling Problem
(Initial Condition)

Project: EXSTART Date: Feb 3, 1994 2:48 PM

#	Resource	Capacity	Unit Cost	Per	Days to Complete	Cost to Complete
1	1-2	1.0	$60,000.00	Fixed	12.0	$60,000.00
2	1-3	1.0	96,000.00	Fixed	24.0	96,000.00
3	1-4	1.0	105,000.00	Fixed	28.0	105,000.00
4	1-5	1.0	37,500.00	Fixed	16.0	37,500.00
5	2-6	1.0	90,000.00	Fixed	20.0	90,000.00
6	2-3	1.0	120,000.00	Fixed	16.0	120,000.00
7	3-5	1.0	70,000.00	Fixed	8.0	70,000.00
8	4-5	1.0	30,000.00	Fixed	12.0	30,000.00
9	5-6	1.0	37,500.00	Fixed	6.0	37,500.00
10	6-7	1.0	62,500.00	Fixed	10.0	62,500.00
11	7-8	1.0	30,000.00	Fixed	8.9	30,000.00

Cost to complete: $738,500.00 Cost of Project $738,500.00

"School" Solution #2 (Continued)

Missile Delivery
Scheduling Problem
(Revised to 56 days)
(After crashing)

Project: EXFINAL Date: Feb 3, 1994 3:07 PM

#	Resource	Capacity	Unit Cost	Per	Days to Complete	Cost to Complete
1	1-2	1.0	$62,500.00	Fixed	10.0	$62,500.00
2	1-3	1.0	96,000.00	Fixed	24.0	96,000.00
3	1-4	1.0	115,000.00	Fixed	24.0	115,000.00
4	1-5	1.0	37,500.00	Fixed	16.0	37,500.00
5	2-6	1.0	90,000.00	Fixed	20.0	90,000.00
6	2-3	1.0	120,000.00	Fixed	16.0	120,000.00
7	3-5	1.0	70,000.00	Fixed	8.0	70,000.00
8	4-5	1.0	35,000.00	Fixed	10.0	35,000.00
9	5-6	1.0	60,000.00	Fixed	4.0	60,000.00
10	6-7	1.0	62,500.00	Fixed	10.0	62,500.00
11	7-8	1.0	30,000.00	Fixed	8.0	30,000.00

Cost to complete: $778,500.00 Cost of Project $778,500.00

APPENDIX C
GLOSSARY

The following is a glossary of basic project management terms.

ACTIVITY — A task or measurable amount of work to complete a job or part of a project.

BASELINE — A defined quantity or quality of performance used as a starting point for subsequent progress measurement. The most common baseline is cost, schedule and performance. Control of cost and schedule would be assisted by project management packages, while each is traded off with performance.

CRITICAL PATH METHOD (CPM) — A technique that assists with determination of early and late start times for activities based upon dependency of other activities and the time required to complete them. Activities which, when delayed, have an impact on the total project schedule, are critical and are said to be on the critical path.

FLOAT/SLACK — The period of time that an activity may be delayed without becoming a critical activity.

GANTT CHART — A graphic portrayal of a project which shows the activities to be completed and the time to complete them as represented by horizontal lines drawn in proportion to the duration of the activity. Some Gantt charts will be able to show the float for the activity.

MILESTONE — An event in the project which marks a control point, major accomplishment or significant decision point.

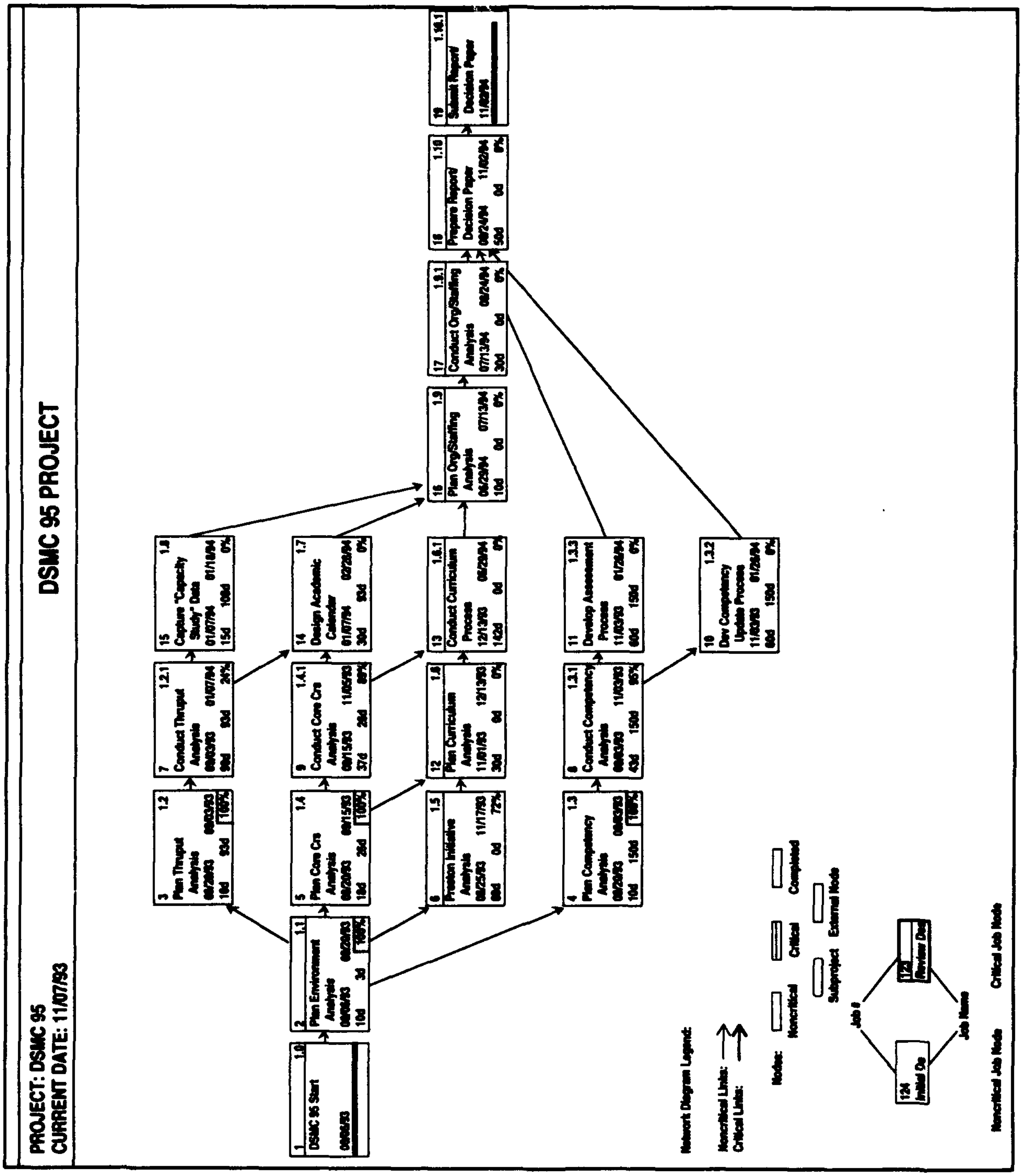
PERT CHART — A graphic portrayal of milestones, activities and their dependency upon other activities for completion of a project; also depicts the project's critical path, which is the longest path of activities for a project.

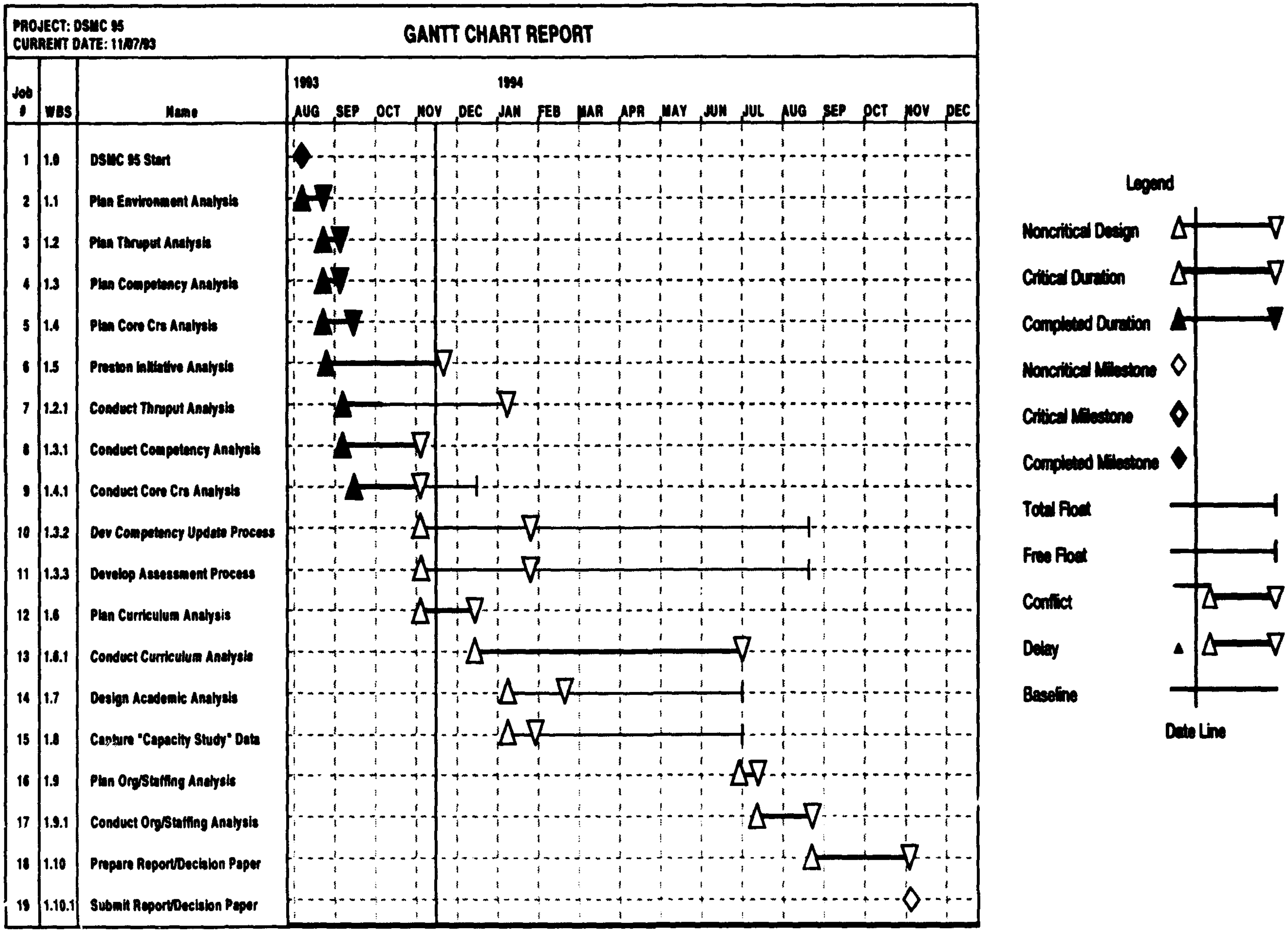
RESOURCE — Any person, tool, equipment or material used to complete an activity or task.

RESOURCE LEVELING — A process whereby resources are sorted out among tasks and activities to identify and avoid conflicts between scheduling and availability.

WORK BREAKDOWN STRUCTURE (WBS) — An organized method used to break down a project into logical subdivisions or subprojects at lower and lower levels of detail. It is very useful in organizing a project.

APPENDIX D
DSMC 95 NETWORK & GANTT CHART




PROJECT: DSMC 95
CURRENT DATE: 11/07/93
GANTT CHART REPORT
Job #
WBS
Name
1993
1994
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1 1.0 DSMC 95 Start
2 1.1 Plan Environment Analysis
3 1.2 Plan Thruput Analysis
4 1.3 Plan Competency Analysis
5 1.4 Plan Core Crs Analysis
6 1.5 Preston Initiative Analysis
7 1.2.1 Conduct Thruput Analysis
8 1.3.1 Conduct Competency Analysis
9 1.4.1 Conduct Core Crs Analysis
10 1.3.2 Dev Competency Update Process
11 1.3.3 Develop Assessment Process
12 1.6 Plan Curriculum Analysis
13 1.6.1 Conduct Curriculum Analysis
14 1.7 Design Academic Analysis
15 1.8 Capture "Capacity Study" Data
16 1.9 Plan Org/Staffing Analysis
17 1.9.1 Conduct Org/Staffing Analysis
18 1.10 Prepare Report/Decision Paper
19 1.10.1 Submit Report/Decision Paper
Legend
Noncritical Design
Critical Duration
Completed Duration
Noncritical Milestone
Critical Milestone
Completed Milestone
Total Float
Free Float
Conflict
Delay
Baseline
Date Line

APPENDIX E
ENDNOTES

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Appendix A

1. Experts from a report by Major John Wade Douglass, *Development of an Integrated Master Schedule for Weapon System Acquisition*, while a student at the Defense Systems Management College, May 1977.

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REPORT DOCUMENTATION PAGE

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This guide was designed to provide the program manager and program management personnel with an understanding of, and a basic working familiarity with, the newest and most effective scheduling methods used in defense systems acquisition. It is particularly useful in the planning and controlling for all phases of a defense acquisition program. The guide includes a discussion of scheduling considerations, methods of scheduling, time management, line-of-balance, and resource leveling. The chapter on automated scheduling tools has been updated to reflect the latest computer software available.

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